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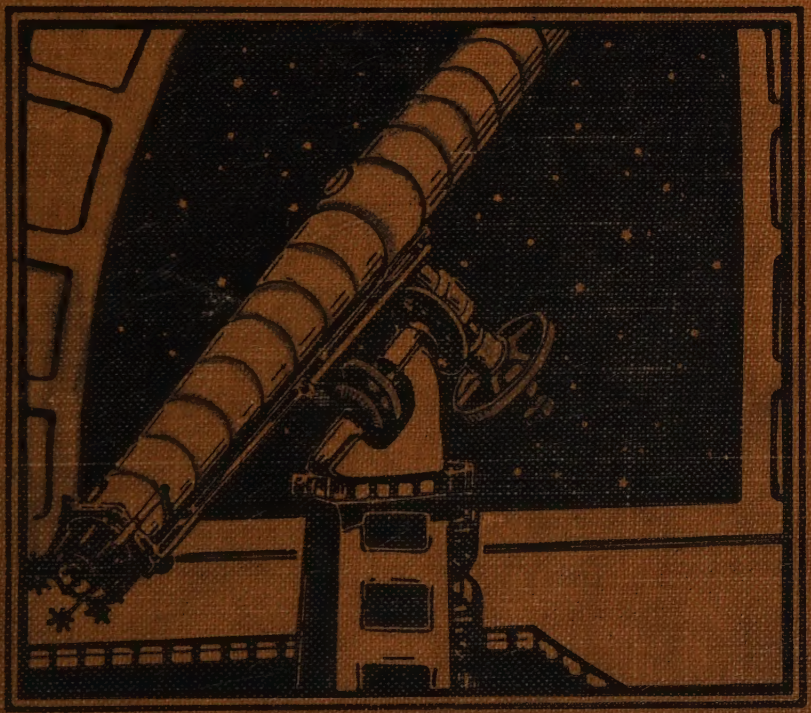

BOOK VI
EARLY MEN of SCIENCE

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SCIENCE READERS

FOR

SILENT READING

BOOK VI

EARLY MEN OF SCIENCE

BY

WILLIAM L. NIDA

AND

STELLA H. NIDA

D. C. HEATH AND COMPANY

BOSTON ATLANTA NEW YORK SAN FRANCISCO LONDON CHICAGO DALLAS

SCIENCE READERS

FOR

SILENT READING

Book IV Animal Life

Book V Makers of Progress

Book VI Early Men of Science

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TO THE TEACHER

The time comes early in child life when little people hunger for Truth. "Is this story true?" asks the child again and again of teacher and parent, and he rejoices deeply when answered in the affirmative. We have no doubt been feeding an unbalanced reading diet—one too heavy with fairy tale and fiction and too light in matters of fact and truth.

It ought not be necessary to present arguments in behalf of science in this scientific age. Many years have gone by since Herbert Spencer first showed the great utility of science as educative pabulum. After a long hard fight science won its way into the colleges and then into the high schools, but how to get some scientific truth into the course in the grammar grades has been difficult to solve.

For many years the authors have been at work on this series searching for material not too difficult and still interesting and worth while, and testing it out in the schools. No one familiar with child interests will deny the strong appeal to him of all animal life. Book III, *The Baby Animal Zoo,* and Book IV, *Animal Life,* have proven highly interesting to children of these grades.

For Book V we have taken the great inventors whose problems make such fine educative material. If our chief business is to teach children to think, here surely is splendid subject matter to this end. Moreover, it is biographical, and the science and thinking are cemented to human action and endeavor. The great popularity of general library books on invention should convince us that we were tardy in seizing upon this material for classroom use.

For Book VI, *Early Men of Science,* the material is also biographical and full of stimulating problems. Here we dip pleasantly into astronomy and other branches of science through the lives of the great men who blazed the difficult pathways.

We have no cocksure method to offer. But in these days of stress on silent reading we wish to point out two vital qualities of good silent reading material. It should be interesting and full of challenging problems for the child mind; and there must be pointed questions to check the understanding. In these respects we submit that this series has few equals.

The authors have doubtless overlooked errors and will appreciate corrections, but the subject matter is fresh and interesting and we send it forth with confidence to the school children of America.

THE AUTHORS.

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The Yerkes Observatory, Williams Bay, Wisconsin

CHAPTER I

GALILEO AND THE TELESCOPE

IN ancient times people knew very little about the sun, moon, and stars. They thought the gods in some manner managed them, and when one of them disappeared from view in an eclipse the people were filled with fear. However, in desert countries like Egypt and Babylonia, where there are never any clouds to shut off the view, men of science gradually found out a surprising number of truths about the stars.

The desert people discovered five stars that moved about in the sky, while all the others that they could see seemed to be stationary. These five moving stars they called planets, which means *wanderers.* They are Mercury, Venus, Mars, Jupiter, and Saturn. Our earth is also one of these wanderers, and now we know there are still others which the ancient men could not see.

The people of those days did not know what made these planets move, nor did they know the paths they move in. We now know that the giant sun holds them from running away into space by the force of gravity, and that these five children of the sun, including the earth and a few others, revolve around him in regular paths. They are the sun's family, and are called the solar system.

What men of those days needed most was a better eye with which to observe the stars. Without aid the human eye can see about five thousand stars only, but with a great telescope we can see hundreds of millions of them.

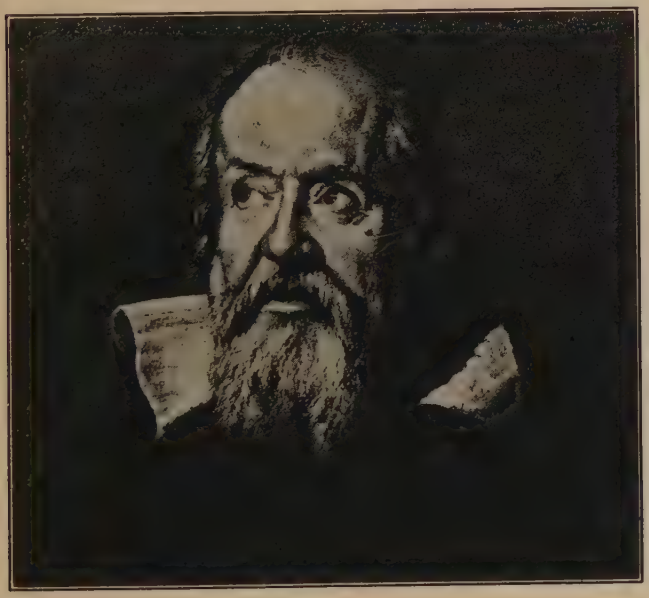
At about the time when John Smith and his colony were landing at Jamestown, a Dutch spectacle maker, named Lippershey, found that if you look through two lenses placed at some distance apart, you can see far-away objects much better, for they are magnified or made to appear larger. A single lens makes what we call a magnifying glass. Nobody had tried two lenses together before.

As soon as Galileo, the astronomer of Italy, heard of this discovery, he thought it would help him to see the stars better. So he made an instrument not much bigger than a toy spyglass, which he called a "looking tube." This was the best eye that had ever been turned toward the stars.

Galileo's full name was Galileo Galilei, but as he grew to manhood he preferred to be known only by his first name. The baby Galileo was born in Pisa, Italy, in 1564. The child was to become one of the greatest philosophers and inventors the world has ever known, but of course no one suspected it then. His father was a merchant of Pisa, a man of some learning who wrote on the science of music. He gave his son the best education to be had in those days.

When Galileo was in the university, he attended church on one occasion in a certain cathedral. Galileo noticed that as the attendant lighted the lamp which

was suspended from the roof, he drew it to him and let it swing back again. So it went swinging back and forth. This was before the days of pendulum clocks. While the choir sang, Galileo watched the lamp with more and more interest. At first it swung wide,



Galileo Galilei

but the arc gradually grew less. Having no watch, he put his finger on his wrist and counted the pulse beats. In this way, he compared the vibrations with his own pulse. He soon discovered that whether the lamp swung in a wide or a narrow arc, it made the same time. This fact surprised him.

When Galileo went home, he began to experiment

with the idea of the swinging lamp, or pendulum, as it came to be called. Soon he had invented an instrument which marked the rate of pulse beats. When he showed it to his teachers, they were delighted. It was not long till physicians were all using the instrument to count the heartbeats of their patients.

Then the clock-makers began to use the pendulum to keep time, and it has to-day many other uses.

Galileo's father wished him to study medicine, but the young man became interested in drawing, and this led to mathematics. Presently he became so absorbed in his new studies that his father had to yield to the bent of his genius. He was now twenty-five,—a handsome, enthusiastic young man, full of hope. His intelligence and wit charmed every circle. He was appointed a teacher of mathematics in the University of Pisa in 1589. In those days educated men studied the writings of Aristotle, the Greek scholar, and whatever Aristotle wrote they believed. Galileo had a questioning mind, and thought every principle or stated fact should be doubted until it was tested by experiment.

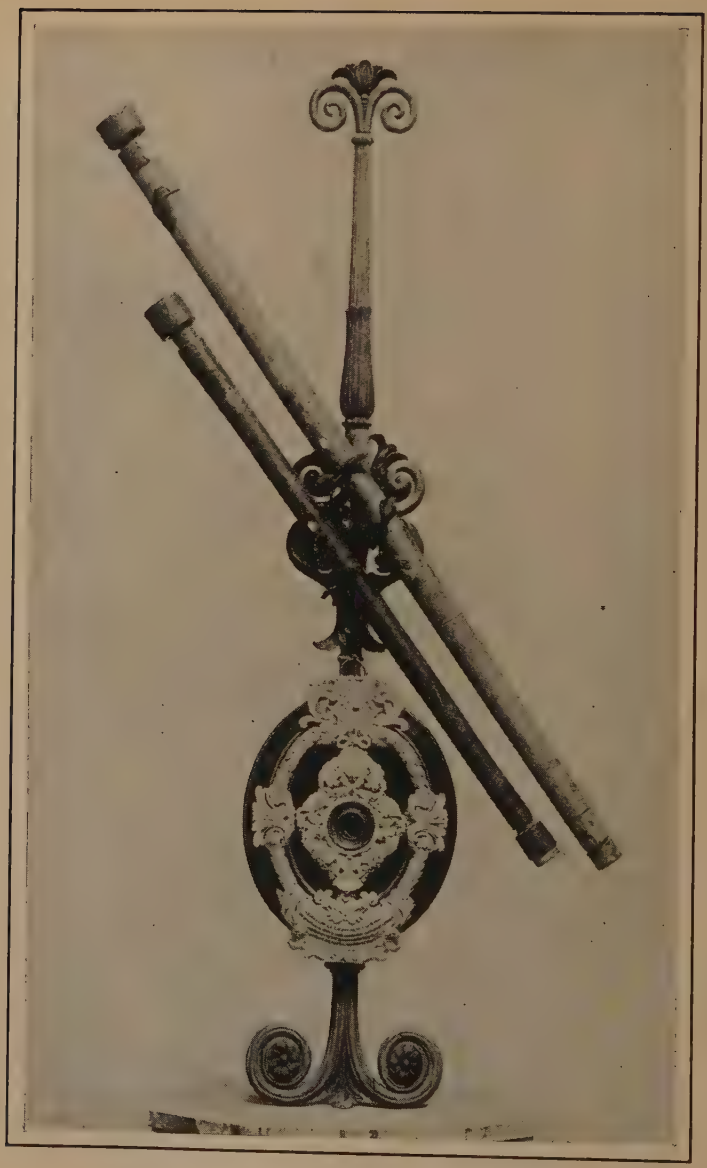
Aristotle said that if two weights of the same material were let fall from the same height, the heavier weight would reach the ground sooner than the lighter, and in proportion to the difference in weight. This had never been disputed until Galileo denied it, and asserted that both would fall in the same time, except with a slight difference due to the resistance of the air. Other wise men laughed at Galileo for presuming to differ from the great Aristotle. But Gali-

leo said he could prove his statement. So one morning he went with some students and teachers to the base of the famous Leaning Tower. He climbed to the top, carrying with him a ten-pound shot and a one-pound shot. Balancing them on the edge of the tower, he let them fall together. Both struck the ground together as he had asserted.

After further study and experiment Galileo gave to the world three great laws of falling bodies, which are studied now in high schools and colleges. He proved he was right and Aristotle was wrong, but he had raised a hornet's nest about his ears, for the other wise men refused to believe even their own eyes. This provoked young Galileo, and he ridiculed them.

Now these men were much older than Galileo. It is neither polite nor wise to make fools of your elders. At last his enemies made it so unpleasant for him at Pisa that he was forced to resign his position, but only to get a better one at Padua. Here he worked for eighteen years, and at the age of fifty-five he was a famous lecturer and the idol of scientific men.

While on a visit to Venice in 1609, he heard that a Dutch spectacle maker had invented an instrument that would bring distant objects near. The rumor of the new invention excited in his mind the keenest interest. He thought much about it, and at last set to work to make such an instrument. He procured a leaden organ pipe and two spectacle glasses, both plain on one side, while one of them had its opposite side convex, and the other its second side concave. He fitted these into the organ pipe, and this crude



Galileo's "Looking tube"—the first telescope

little instrument became a telescope. It magnified things three times, or brought them to one third of their real distance.

With this "looking tube" Galileo saw hosts of stars never seen before. He looked at the group of six stars which are called the Pleiades, and instead of six he saw thirty-six stars. He looked at the bright belt across the sky at night which we call the Milky Way, and found it consists of multitudes of stars clustered together. He turned his spyglass on the moon and brought it three times nearer. It was like making a voyage across an unknown sea and discovering new lands. Galileo was delighted.

Galileo carried his "looking tube" in triumph to Venice. It was regarded as only a toy; yet everybody wished to see an instrument that increased the power of the human eye. All the great men in Venice wished to see it and were much delighted. They climbed to the top of the highest church tower in Venice in order to see ships, so far off that it was two hours before they could be seen without the spyglass, apparently steering full sail into the harbor. The spyglass made ships fifty miles off appear as large as if they were only fifteen miles distant. After Galileo had spent a month showing his telescope to the learned people of that wealthy city, he received an increase in his salary at Padua and was made professor for life.

Galileo now desired to use his telescope to make still more discoveries in the heavens, but his instrument was too small. He made another and larger telescope which magnified eight times, and then another

which magnified thirty times, and pointed it at the moon. His heart leaped with joy, for he saw what no human eye had ever before seen—ranges of mountains, deep hollows, and broad plains! His enemies would not believe his report and even refused to look through the instrument. Galileo next turned his telescope on the planets and found they appeared with disks like the moon at a quarter full. He turned it on the Milky Way and beheld innumerable tiny stars.

On the seventh of January, 1610, he turned his new telescope on the planet, Jupiter, and observed three little stars near the body of the planet all in a straight line, two on the east and one on the west of Jupiter. The next time he observed them he found they had changed places and were all on the west of Jupiter. The next observation showed that they had changed again. He later discovered that instead of three there were really four of these little stars revolving around Jupiter.

"What can they be?" thought he. "They are not fixed stars, neither are they planets; so they must be moons. Jupiter, like the earth, has moons, but instead of one moon it has four."

More than that, Galileo observed how long it takes each moon to revolve about its parent. One goes around in forty-two hours, and the others range up to seventeen days. Galileo then turned his telescope on the sun and saw great sun spots. His friends believed him and began to call him a genius.

His enemies were dismayed, but resolute. One of the professors at Padua would not even look through

the wonderful instrument. Others ridiculed his discovery. Yet many of the wise and great of Italy were admirers and companions of Galileo and praised his immense service to astronomy. Galileo wrote statements of his discoveries and sent these with his telescope to the princes and learned men of Italy, France, and Germany. They were received with greatest enthusiasm and put to use at once in the hope of finding new stars.

At last Galileo discovered that the spots upon the sun move across its face. By close observation of the sun spots he found that the sun rotates like the earth, but only once in about twenty-eight days.

Galileo had now attained his highest ambition, for he was at the head of all scientific men of Europe. Men came from all parts of Europe to study under him. But there is no height of fortune from which a man may not fall, and it is usually the proud and scornful in spirit who do fall. Galileo continued to irritate his enemies by his proud and boastful spirit. He heaped scorn upon them and made fun of them. They replied that they "refused to be dragged at his chariot wheels."

The churchmen were especially hostile. They thought Galileo was trying to undermine the Bible, and they were eager to attack him. He wrote a long letter in which he said that the Bible was not intended to teach science, but to point out the way of salvation.

Together, his enemies gathered all the evidence they could find against him, and he was summoned before a court of churchmen. Most of his judges knew little

about science, so they decided that he must either go to prison or give up his new beliefs about the earth revolving around the sun. Galileo, in dread of prison, pretended to renounce his doctrines. He did not keep his promise to be silent about them, however, and at the age of seventy he was put in prison for the rest of his life. Here he was kindly treated, though not allowed to visit his friends.

Then the great scholar lost his daughter, to whom he was devoted, and her death plunged him into despair. He also lost his health, and presently became deaf and blind. The eyes that had seen more of the heavens than the eyes of all who had gone before him were sightless.

Galileo passed away at the age of seventy-eight, and was buried without a monument because he died a prisoner. But to-day he is honored as a great benefactor of the world; his discoveries are held in grateful memory; and a monument has been erected to him at Florence, Italy, where he was buried.

Questions and Problems

1 Why was so little known about the stars till the days of Galileo?
2 What qualities did Galileo possess that made him so great as a scientist?
3 Do you suppose it took courage to differ from the great Aristole?
4 Is it wise to doubt an experiment in search of truth?
5 What experiments have you made?
6 If a pendulum clock is gaining time, should you lengthen or shorten the pendulum?
7 Take a common superstition, such as the number 13 or 23, or a horseshoe or rabbit's foot, and experiment till you are satisfied that the belief is true or false. Make a list of superstitions.
8 See if you can find in a book of physics Galileo's laws of falling bodies.
9 Would you rank Galileo as one of the greatest men of history? Why or why not?

Home experiment: Read carefully, follow directions, and try to state a fact or law.

Tie a string 40 inches long to a small stone and swing the stone, holding the end of the string. Count the swings in 60 seconds. Repeat this, using a string 10 inches long.

CHAPTER II

WILLIAM HERSCHEL DISCOVERS A NEW PLANET

AFTER the splendid beginnings of Galileo in astronomy, many men began diligently to improve telescopes and to study the stars. By 1669 there were telescopes that magnified thirty-eight times. Fifty years later a telescope was made that magnified two hundred times. The largest telescopes of to-day magnify more than one thousand times.

The chief use of a telescope, as we have read, is to make far-away objects look nearer to us; to see an object miles away as if it were, perhaps, only a few yards off. Telescopes are made to do this by means of large, well-polished lenses like those used in a pair of spectacles, but much larger and more nearly perfect. These lenses collect the light rays coming from an object and bring them together to form an image or picture.

The lens type of telescope has a large lens or glass at one end of the tube, and a small lens, called the eyepiece, at the other. The use of the large lens is to act as a sort of gigantic eye. It collects a large amount of light and brings it to a focus within the tube, making a bright image or picture, while the eyepiece magnifies this image. All great telescope makers have been artists. Among the foremost of them was William Herschel.

Herschel was born in Germany in 1738. His father was a musician in the army. In his earliest years

the lad heard a great deal of music in the family sitting room. The father's salary was small, and the family often lacked food and clothing; but for all that there was not a happier family in the city.

The father had the keenest love for music. When his hours of duty and teaching were over, he gathered his children around him, each with an instrument, for a family concert. He trained the little performers with the greatest care, for he thought that no matter what happened to them in the future, they could still earn their way by music.

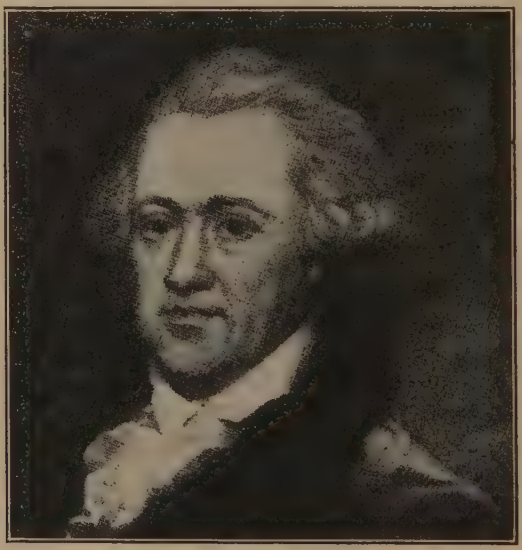
William, very early, showed not only a keen taste for music but much talent for discussion, and the father talked to the family about everything in which they were interested. Sometimes, before the evening was over, they would all go out of doors and spend an hour in studying the stars, but it was quite understood that all of the sons were to be musicians.

In order to give them an early start in their profession, the father often allowed them to take part in public concerts, for their talents were so unusual that, even as children, they were given solo parts to play.

The boys attended the garrison school in Hanover, where they obtained their education, and the father continued to help them in the evenings.

It was necessary for the children to aid in the support of the family as soon as possible; so William, while yet only a lad, entered the Guards as oboe player. Still the evening concerts at home continued. William remained in the army for four years, one year of which was spent in England.

At the age of nineteen, young Herschel left the Guards on account of delicate health and returned to England, with the hope of being able to earn his living there. The thought of being homeless and friendless in a foreign land did not dismay him, for he could speak English well enough to make himself under-



Sir William Herschel

stood, and could play the oboe, violin, and organ so well that he was sure of a living. So he began his new life in England with a brave heart.

For some years the young musician wandered from town to town with his music till finally he played before Dr. Miller, a noted organist of Durham, who was so delighted that he invited young Herschel to come

and live with him. Herschel gladly accepted, and Dr. Miller did all that could be done to advance him in the musical world until his success was certain.

Herschel was soon playing first violin in the popular concerts of Durham and had as many pupils as he could teach. Presently he became the organist of one of the leading churches in Bath. He began to publish his compositions, and had the satisfaction of seeing them favorably received by the public.

It was in Bath that Herschel came upon a book on astronomy. He was so fascinated with it that he pored over it every leisure moment of the day and spent long hours of the night in studying it. He even took it to bed with him. His interest turned to astronomy, and so absorbed did he become in studying the stars that he wished to scan the heavens for himself, but there was neither a telescope to which he could get access nor one which he could buy. Consequently the musician took up the study of the mathematics which was necessary to design a telescope.

After Herschel had mastered the design, he began the grinding of mirrors with his own unskilled hands. To grind mirrors was easier than to grind lenses. The first results were only fair, but they were encouraging. When the nights were clear, he searched the sky with such telescopes as he had made. When they were cloudy, he worked on new mirrors. Better and still better ones were made, even up to four feet in diameter, and with each one, Herschel made one discovery after another in the sky. Whatever he attempted, he planned very carefully, and then made a

thorough job of it. This was the secret of his great success.

So interested was Herschel in the stars that he dismissed some of his music pupils to get more time with his telescope. His brother and sister, who had come to live with him, were drawn away from their music and pressed into the work of making telescopes. The house was soon turned into a huge workshop where stands, tubes, and mirrors were made as fast as possible.

Herschel was so engrossed that he would not leave his workshop even for his meals, and it is said his sister could at times induce him to eat only by standing by his side and putting food into his mouth as he worked. When at concerts where he led large orchestras, he often rushed outdoors between the acts to snatch a few glimpses of the heavens. His devotion soon brought forth telescopes far better than any that had been made, and he began to sell them to increase his income.

Wishing to study all of the stars thoroughly, Herschel made a map of the heavens in sections so as to give careful attention to each part. He seldom went to bed on a clear night in winter or summer while the stars could be seen.

While engaged in a study of the planets, he noticed the curious appearance of a white spot near to each of the poles of the planet Mars. After much study he concluded that the seasons on Mars were much like those on the earth, and the white patches were probably snow. This belief exists to-day.

One night Herschel noticed a star of different appearance, and much larger than the small stars near it. He observed it carefully for two or three nights and saw that it did not sparkle as did the others, but shone with a steady light and appeared to change its place. He, therefore, decided that he had found a new comet.

When Herschel announced the discovery to the world, all the astronomers of Europe turned their telescopes on this interesting object to observe its motions and to calculate from them the size and shape of its path. It was soon found that the new comet did not move in a long orbit like other comets, but that it was traveling in a path more nearly round like that of the earth and other planets. It was not long until all astronomers agreed that it was not a comet at all, but that Herschel had really discovered a new planet.

Men of science were greatly excited by this discovery. It was not only the greatest that had been made by the telescope since the splendid work of Galileo, but the greatest that had ever been made. The other planets had all been known as far back as the memory of man, but here was a new planet moving around the sun, unknown and unseen through all the countless ages of the world.

This discovery created a new interest in astronomy. All eyes were turned with eager gaze to the starry fields of heaven, for who could tell what new wonder might be found in the far, dim fields of space.

Many honors were showered upon him who had read the secret. It was the more remarkable because his studies had been mainly those of a musician. Herschel

wished to name the new planet after George III, King of England, but other astronomers objected. Some said it would be better to give it the name of one of the old Greek gods, like the other planets. It was finally named Uranus, after the oldest of the gods.

A star cluster called the Pleiades

Uranus was discovered on the thirteenth of March, 1781. This was five years after our Declaration of Independence. Men now said that the labors of such a genius as Herschel should be given to science alone. Accordingly, the king granted him a pension which

enabled him to give up the work of teaching music.

Soon after this Herschel built an immense telescope, forty feet long with a lens four feet across, which greatly aided him in his survey of the sky. On the day after it was completed, he turned it upon Saturn and saw that the planet had six moons instead of the five which were already known. A few weeks later he found a seventh moon of Saturn which is the one nearest to the planet. A few years later he found that Uranus was furnished with two moons. This discovery filled Herschel with delight, as it was more proof to him of the wonderful harmony of the universe. But before making it known, and in order to be perfectly sure that he had not been mistaken, Herschel made a sketch or drawing of Uranus and his moons as they should appear on a certain night. When the hour came, he was greatly delighted to find that the group appeared exactly as he had pictured.

Herschel made many other discoveries regarding the stars and the sun. Newton had proved that all the planets, together with their moons, move around the sun, held by the law of gravitation. Herschel after a deep study proved that the sun, with all his planets, is also moving through space at a marvelous speed around one of the remote stars, but just which one we do not know.

Herschel proved that all the stars which were thought to be fixed really move. They are, however, so far away that we cannot calculate their paths. If we could only view the heavens as they really are, scientists say we should see many, many systems like the

sun and his planets all moving about in a wonderful plan.

In 1822, at the age of eighty-four, Herschel died. He kept his great mental powers until the last, claiming with truth that he had looked farther into space than any other eye had yet seen.

Questions and Problems

1 How came Herschel to be interested in astronomy?
2 Tell of his discovery of Uranus.
3 With a lens or watch crystal try to start a fire in the sun. Explain why this can be.
4 Examine an opera glass to learn of the lenses.
5 Why do some people wear spectacles? How do they aid the eye?
6 Get the best opera glass or telescope you can and survey the moon. Tell what you saw.
7 Tell how a telescope is made.
8 At first Herschel knew nothing of telescopes. What qualities made him succeed?

CHAPTER III

SIR ISAAC NEWTON SOLVES A GREAT PROBLEM

WE now have two kinds of telescopes. One kind uses lenses to gather light and bring it to a point or focus. The other kind does the same thing by using mirrors. The lens type is called a *refractor,* and the mirror type, a *reflector* telescope.

The man who invented the kind using mirrors was Sir Isaac Newton, another of the great men of science of all the ages. Newton was born in England many years ago. The family lived on a little farm where the boy grew up.

Isaac was soon in school, learning to read and write, but he was not very fond of his books. He often stood at the foot of his class. One day on the way to school, a lad who stood just above him in class gave him a kick which caused Isaac severe pain. In a rage he dared the other boy to fight, and they went into a churchyard near by to settle the difficulty. When all was ready, young Newton, who was smaller and weaker than the other lad, gave the bully such a good pounding that he promised to mind his own affairs.

Isaac felt the insults which were heaped upon him for being a poor student, and resolved to prove that he was no fool. So he set to work in earnest, and it was not long before he stood at the head of his class.

Still, he liked to make things with his hands better than he liked to study. When only a boy, he made a windmill and placed it on the roof of his home, where

the wind set it in motion. Some days the wind refused to blow, however, and the lad was disappointed. He then determined to make some improvements in his windmill. Not wishing to turn the mill himself, he made a tread-wheel. Then he caught a mouse, which he caged. The mouse, to get some corn placed just out of reach, kept the mill going by walking on the wheel.

Next Isaac made a clock that would run by water power. In those days there were no clocks or watches with springs in them to keep them going. Isaac's water clock stood about four feet high. It had a dial plate at the top, with figures for the hours and a hand that pointed to the right time. Every morning the lad poured in enough water to keep his clock running all day.

You may be sure that Isaac as a boy was an expert in making kites, but a simple kite did not satisfy him. He made a paper lantern with a tallow candle inside. On dark nights he tied the lantern to the tail of his kite, and he and his friends watched the burning candle go bobbing around in the dark sky. The neighbors looked up and wondered what the queer light could be. Some people said it was a comet or wandering star. This amused the boys very much.

Isaac also made sundials to give the correct time of day. A hundred years later these sundials were still seen at the manor house where Isaac Newton lived as a boy.

When he was fifteen, Isaac's mother decided he was to be a farmer, but when she sent him to watch the cattle, she found he was not to be trusted. He became

interested in a brook, or in making water wheels to run in the brook, while the cattle wandered away and enjoyed themselves in a neighbor's cornfield. He did not intend to disobey his mother, but his mind was always bent on making things.

Newton, the discoverer of the law of gravitation

So instead of becoming a farmer Isaac was sent to college, where he showed after many years what a good mind he had. He especially liked the study of the stars, or astronomy. In those days people knew very little about the stars. Isaac made wonderful

discoveries, and by using mirrors he invented a new kind of telescope which wise men praised highly. He was soon known as a great man.

One day, it is said, while sitting alone in his garden he saw an apple fall to the ground. "What makes heavy things always fall to the ground?" thought he. Then he began to think and study, and to ask himself questions like this, "Will an apple fall from the mountain cliff?" And to this he answered, "Yes!" He kept thinking about this earth-pull that makes objects fall to the earth until he discovered some wonderful laws. So wonderful and so true are they that every boy and girl who studies Physics or Astronomy nowadays must learn Newton's Laws.

Kepler had discovered the laws that explain the motion of the planets, but still the great question remained: What gives the planets their motion and carries them around the sun? Newton, when only in his twenty-fourth year, solved the problem. He explained this motion so simply and clearly that no doubt remained. He said all objects on the earth are held there by magnetism, or the force of attraction. He said the earth was a great magnet which held all things upon it in their places and kept them from flying off into space.

Newton proved further that if the earth attracts things close at hand, like the apple that falls, it would also attract things far off, though in a less degree. The moon, he said, goes around the earth because of this earth-pull, and the earth goes around the sun because of the sun-pull. It is the same kind of pull that

makes the moons of Jupiter go around that planet. The more distant the objects are, the less the power of attraction; and the bigger they are, the greater the attraction. This attraction Newton called *gravity.* After Newton had proved this force by many calculations and experiments, he gave to the world his great law, which is this:

"Every particle of matter in the universe attracts every other particle with a force depending upon the weight and the distance."

A body twice as heavy as another body exerts twice the pull of the other body, and a body at twice the distance exerts one fourth the pull or force. This law of gravitation explains the motions of the moon, the planets, the sun, and the stars. It has been called the greatest discovery ever made by the human mind.

So delighted was Newton when he learned that this law had stood all the tests that he was wild with joy. "Nothing holds me," he wrote. "I will indulge my sacred fury. I will boast of the golden vessels I have stolen from the Egyptians. If you are angry, it is all the same to me. The die is cast; the book is written, —to be read either now, or by posterity. I care not which. It may well wait a century for a reader, as God has waited six thousand years for an observer."

Many other discoveries were made by Isaac Newton, and the world still honors him, though he has been dead for two hundred years. In the next chapter we shall learn more of the reflector telescope which he invented.

Questions and Problems

1 How could a clock be made to run by water? By sand?
2 Newton's greatest gift to man was the *law of gravity.* What is gravity?
3 Find a description of Newton's law of gravity in some physics text and tell about it.
4 What kind of telescope did Newton invent?
5 How did Newton explain the motion of the moon and planets?
6 Read all you can find about Newton in your reference books.

Home experiment: Put a cup of water in a small pail and swing the pail over your head vertically.

CHAPTER IV

ALVAN CLARK, THE MAKER OF TELESCOPES

THE making of a great telescope is a difficult task. But more difficult than all the rest is that of making the big lens, or object glass. It has to be done so very accurately. If the glass in any part is too thin by a hundred-thousandth part of an inch, it spoils the image. So the man who polishes the lens must show great skill.

Then, besides the extreme care in polishing, it is very difficult to make the glass in a large lens of the same quality or purity in every part. Every inch of the glass must be exactly like all the rest, or the picture is blurred.

In the early days many people tried to make a large lens by fitting together different pieces of glass, each of the proper shape. The idea seemed good, but it could not be done that way for the reason that two pieces of glass cannot be made that are exactly alike. The entire lens must be formed of the same molten glass under exactly the same conditions.

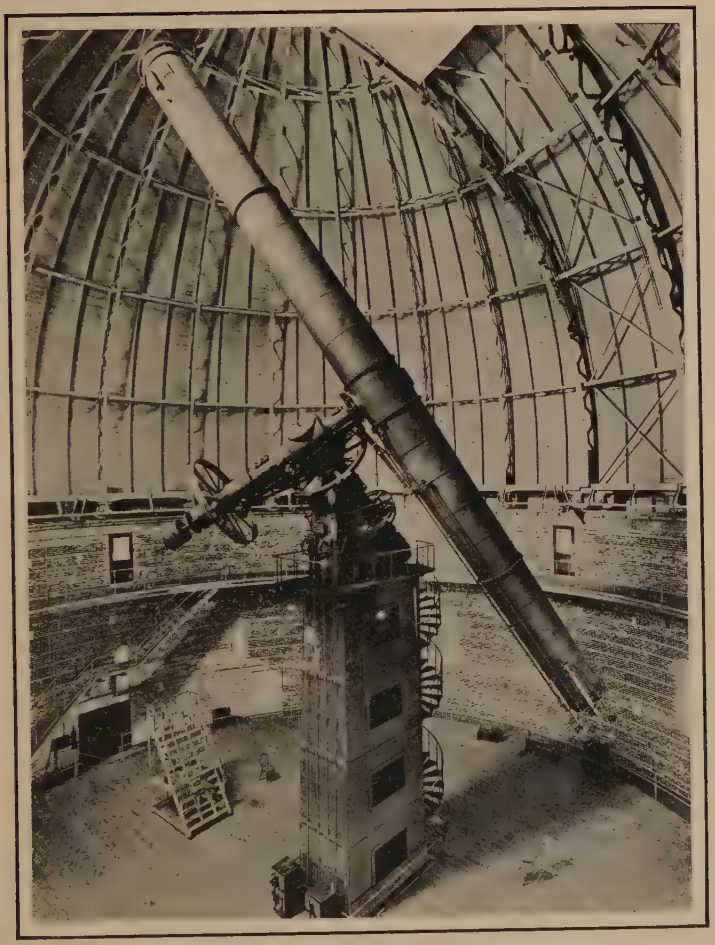
Of all makers of telescopes, Alvan Clark and his son, Alvan G. Clark, have been the most successful and the most celebrated. The elder Clark was a portrait painter of Boston. In 1844 he became interested in the construction of a little reflector telescope. He was by nature careful and precise in his work; so he was just the man to make mirrors and lenses. Clark met with amazing success. Five of his reflectors were

purchased by the English astronomer, Dawes.

The Clarks made seventy-five telescopes having an aperture of more than six inches. They were so nearly perfect that no other maker has been able to equal them. Five times between 1860 and 1895 the Clarks made telescopes which were larger than any then in existence. Among their greatest instruments are the 23-inch telescope at Princeton, the 24-inch telescope at Flagstaff, Arizona, the 26-inch telescope at Washington and a similar one at the University of Virginia, the 30-inch telescope at Pulkowa, Russia, the 36-inch telescope at Mount Hamilton, California, and the 40-inch Yerkes telescope at Williams Bay, Wisconsin. The Yerkes telescope was the last work of Alvan G. Clark, and for twenty-five years it stood as the largest refractor in the world.

In the reflector telescope, instead of a large lens at the top of the tube, a large saucer-shaped mirror is placed at the bottom. It reflects the light that falls upon it to a focusing mirror and from there to an eyepiece. The Mt. Wilson telescope has a mirror over one hundred inches in diameter. It cannot be used to study the sun because the heat of the sun's rays would expand the mirror and distort the image reflected by it. For studying the sun, a lens type like the great Yerkes telescope on Lake Geneva, Wisconsin, is used.

The largest telescopes at present are reflectors. It is much easier to construct a very large mirror than to construct a very large lens; it is also cheaper. A mirror, however, is more likely to get out of order than is a lens, and any irregularity in the shape of the mir-



The Yerkes Telescope—40-inch lens

ror produces a greater distorting effect than an irregularity in a lens. The lens type is also more convenient to handle. For these reasons refractors are still made.

Another instrument that has aided the scientists in their study of the heavens is the spectroscope. With this instrument the light coming from the sun or a star can be analyzed and be made to give up many secrets. Thus we can find out from the light of a star whether such elements as iron, copper, gold, or hydrogen are found there. It is difficult to describe the spectroscope briefly so you can understand it. This subject will be left for your study of physics in high school.

After the spectroscope there came another tool that is wonderfully useful to the astronomer. It is photography, or the science of taking pictures. The eye may forget what it sees, but the photographic plate will hold it accurately.

The first picture of the moon was taken in 1840 by Dr. John W. Draper. Instruments were made and improved, and remarkable pictures of the stars and of comets are now taken. The motion and distances of each of the stars can be measured by photography. The astronomer does not have to keep his eye at the eyepiece of the telescope to see the heavens. Instead, he exposes a sensitive plate which will patiently wait as long as he wishes. Then he can study the picture at his convenience.

In the star group known as the Pleiades, most people can see only six stars with the naked eye. If one has

40-inch lens ready for mounting. Left: Alvan Clark

especially keen sight, he may be able to make out from seven to fourteen stars. But with the telescope and the photographic plate, nearly three thousand stars have been found in this one constellation.

Questions and Problems

1 Why is the making of a big lens an exacting piece of work?
2 How is a reflector telescope made?
3 Who were the great telescope makers? Locate some of Clark's telescopes to-day.
4 Why is the reflector type not suited to study the sun?
5 What idea did you get of a spectroscope?
6 How has photography helped in the study of the heavens?
7 What is a constellation?

Home experiment: Hold a page of a book before a mirror and read in the mirror. Try two mirrors, reading from the second.

CHAPTER V

THE SILVER MOON

THE moon is the only one of all the heavenly neighbors that is near to us, but, as we shall see, even the moon is not very near. Suppose we build an imaginary railroad to the moon. How long would it take an express train going forty miles an hour to reach that globe? If it went a thousand miles in a day and a night, it would take two hundred and forty days to reach the moon. That is about eight months of traveling night and day at forty miles an hour. If we started when school opens in September, we should not reach the moon until April the following spring. When we arrived there, we should be almost a year older than when we started.

Because the moon is so far away, it looks no bigger than a basket ball; but it is really very large. You do not think a globe small if it has a diameter of two thousand miles. Think of the distance from Chicago to San Francisco as the diameter of an immense ball, and you have a globe about the size of the moon.

With the Lick telescope on Mount Hamilton, California, the moon can be magnified a thousand times. We can see the moon as if it were a thousand times nearer than it really is. If we magnified it a thousand times or brought it a thousand times nearer through the telescope, we should see the moon only two hundred and forty miles away. It would appear as if the

moon were at Cleveland and we were at Cincinnati. In the larger Mt. Wilson telescope the moon is brought to within fifty miles of the earth. Through this telescope you could see a large city on the moon, if one were there, or even a very large building like our Capitol at Washington. However, there are no such cities or buildings on the moon. We could even detect a big airship as a moving speck against the surface of the moon, but we find no signs of man's work there. Astronomers have looked for them thousands of times.

When we look at the moon through a telescope, we can see that it has no signs of water. We could see a large river valley if any were there. No deep canyons can be discovered in the mountain sides; neither are there clouds, so there must be no water.

Astronomers tell us that there is no atmosphere about the moon. Now if there is neither water nor air, what can we say about people and animals, about trees and plants, on the moon? It would be hard to imagine an animal that could live without air and water. Because there is neither air nor water on the moon, it can have no weather. It is so cold on the moon that no man could possibly live there for an instant. It is thought to be a frozen ball because it has no coat of atmosphere to hold the heat that the sun gives it.

You know that our atmosphere serves as a blanket to the earth. This air blanket prevents the escape of heat from the earth and also shields us from too much heat from the sun. Since the moon has no atmosphere at all, you can imagine how very hot it must be underneath the sun's direct rays, for they fall five times

Lick Observatory, Mt. Hamilton, California

hotter on the moon than they do on the earth. On the other hand, how piercingly cold it must be during the long night there. The moon cools down to 250 degrees below zero. This is cold enough to freeze air.

One great astronomer, Professor Pickering, thinks that he can see signs of some sort of feeble life or movement on the moon. He speaks of a very thin atmosphere and of occasional light falls of snow. But other astronomers do not take this view. They agree that neither air nor water can be found.

One strange thing about the moon is that it always keeps the same face or side toward the earth. We have never seen the other side of the moon, so we do not know what that side looks like. The moon turns only once on its axis every time it goes around the earth; that is, once about every twenty-eight days.

For fourteen of our days there is continuous night on the moon, and the temperature must sink very low toward the absolute cold of space. Then will come full daylight for fourteen days when the sun's rays blaze down with no atmosphere or clouds to absorb the heat or light. Astronomers are not agreed as to how warm the days on the moon may be, whether the temperature is always below freezing, or whether during the long days it goes above the boiling point of water.

There is an enormous number of craters, or huge pits, on the moon's surface. Some think these craters were made by very large meteors falling into the moon. Other astronomers think these craters are the remains of gigantic bubbles of gas which were raised on the

moon's skin by the heat of the sun. Still others think they are craters of dead volcanoes. Our craters on the earth are generally deep cups; whereas those on the moon are broad, shallow saucers. Clavius, the largest of them, is one hundred and twenty-three miles across. Yet the rim of this crater is not a mile high.

—*Lick Observatory*

The Moon—Observe the mountains and craters

The mountains on the moon rise to a great height and are very rugged. They are like fountains of lava and rise in places more than five miles high. Our earth mountains are continually being worn down by frost, ice, and water, but as these elements of the atmosphere are not found on the moon, its mountains are "everlasting hills."

So far as we can see, not the slightest change ever takes place on the moon. A stone lying on the earth's surface is continually attacked by the weather, and in the course of years it is gradually worn away by the wind and water. But there is no weather on the moon, and a stone lying on its surface might rest there undisturbed for unknown ages. The surface of that body is heated when the sun shines upon it, and it cools when the sun has set. Except for these changes in temperature, there is nothing going on over the whole round surface so far as we can see.

The soft silvery moonlight, which we all enjoy so much, is the light which the moon catches from the sun and reflects to us on earth. The moon itself is cold and solid, and sends out no light of its own. Like a great, round, rough, silver mirror it catches what sunlight it can and sends it to the earth. If you will look closely when the moon is new, you will see not only the bright crescent but also the faint outline of the whole round moon. The crescent is the part that is receiving sunlight, while the dim part is seen only because the earth is shining like a moon upon it. You must remember that to the moon our earth is also a moon, and because the earth is so much larger, the earthshine is almost fourteen times as bright as moonshine.

It would be pleasant to think of boys and girls on the moon, and grown-ups, too, all enjoying our earthshine, but we know that there can be no people there, nor flowers, trees, or life of any kind.

Let us imagine we live on the moon. How will the earth look to us? It will then be our moon, and it will

be a many times bigger moon. But it will not rise and set, for the moon always keeps the same face or side toward the earth. We might live on the other side of the moon and never be allowed to see the earth at all. But if we see the earth, it will behave just as our moon does, except that it will always be seen about the same place in the sky. Sometimes the earth will be dark; then new-earth, half-earth, and full-earth. If it looks about fourteen times as large as our moon, then when night comes on the moon, the earthshine will surely be very bright, especially when the earth is full.

If we were to imagine ourselves living on the moon, we should have to think of doing without all the things that we enjoy from air, water, and snow. There would be no storms or winds, no clouds or anything flying overhead. There could be no sounds, because sounds are air waves. We could not talk with the voice; therefore we should need some sign language.

While on the moon, we should see no shooting stars, since these are meteors passing through atmosphere and are being burned up by it. From the moon the sky would be black; not the lovely blue which is due to the earth's atmosphere. Scientists have proved that light consists of three colors—red, yellow, and blue. There are three parts of the yellow, five of the red, and eight of the blue; and these three colors make black. The earth's atmosphere sifts out the other colors and leaves us a blue sky, but the moon, having no atmosphere, has a sky as black as coal. However, the stars would shine all night and all day in the black sky of the moon.

We should be able to see from the moon the gigantic flames of burning gas streaming out from the sun all the time, which only astronomers have been fortunate enough to observe when there is an eclipse.

When the moon comes exactly between the sun and the earth, the moon shuts off the light from the sun and leaves us in darkness. This is called an eclipse of the sun. This darkness lasts only a few minutes, as both the earth and the moon are moving very rapidly, and presently the moon is out of the way and the sunshine returns to us.

There is also an eclipse of the moon. This is caused by the earth's getting between the moon and the sun so as to cut off the sunshine upon the moon, for you remember we see the moon only when the sun is shining upon it.

Astronomers often go on long expeditions with their telescopes to observe an eclipse, for it may not be seen at all places on the earth. The scientists must work rapidly to make observations in the three or four minutes during which the eclipse lasts. Sometimes clouds shut out their view of the sky. This is a keen disappointment to the astronomers who have their telescopes ready to learn something new during these unusual times.

When the earth turns round, we do not fall off because the earth-pull, called *gravity,* holds us to the ground. Since the moon is so much smaller, the force of gravity there is only one sixth as much as it is on the earth. On the moon you would weigh only one sixth as much as you do here. You could run six times

as fast, jump six times as high, or bat a ball six times as far. How would you like to play outfield on a ball team on the moon?

Though a dead world, the moon is a wonderful companion of the earth. Its changing form is interesting. People of years ago believed it had great influence on our crops.

Questions and Problems

1 Why is the moon thought to be a frozen ball?
2 Explain why we have never seen but one side of the moon.
3 Contrast conditions on the moon with those on the earth.
4 Look at the moon with opera glasses and then describe what you saw.
5 Why are the mountains on the moon more fixed and stable than ours on the earth?
6 How would the earth appear from the moon?
7 What is an eclipse and how caused?

Home experiment: Hold your left palm upward. Upon the tip of your forefinger place a small card and on top of the card just over the finger tip a nickel. Try snapping away the card with the thumb and middle finger of your right hand until you can leave the coin on your finger.

CHAPTER VI

THE SUN

OUR sun is a great, fiery ball, a hundred times as great in diameter as the earth, and more than a million times as large. But, strange as it may seem, the sun is only a star like the other stars that we see in the sky at night. Stranger still, we find that our sun is only a medium-sized star. It is not so large as the Pole Star, and not nearly so large as some of the others. The sun, compared with other stars, looks large to us because we are nestled close to it. If the sun were gradually to move farther from the earth until it was as far away as the other stars, its light would grow so dim that its glory would be gone.

We have read that an express train would require eight months to make the run to the moon. How long do you think it would take us to go to the sun, which is nearly four hundred times as far from us as the moon? It would take an express train two hundred and fifty-five years for such a journey. Two hundred and fifty-five years ago the Pilgrims had just settled in America. If they had started at that time on an express train, they would just now be reaching the sun.

If we were to make a journey to the sun, we should find an express train entirely too slow; for not only would we die before reaching there, but our great-grandchildren would not live out the journey. We shall have to find some faster way of travel, for even an airplane would take too long. We know that a can-

non ball moves at a tremendous rate—twenty or thirty miles a minute. It would move thirty thousand miles in a day. Eight whole days would be necessary for a journey to the moon. But it would take our cannon ball seven years or more to reach the sun.

Now let us think of the distance to the sun in another way. We know that the sun is very hot. If you had

—*Lick Observatory*

The sun hidden behind the moon

an arm ninety-three million miles long and sat in your home with your finger on the sun, you would be burned. but how long would it be before you would know that you were burned? The pain travels five feet in one twentieth of a second. If you put your finger in the

fire, you are burned before you feel the pain. It is felt one hundredth of a second after you are burned. Now, if you should stick your finger in the sun with your long arm, you would wait a year and not feel the pain. You would wait ten years and yet not feel it. It would take the pain one hundred and fifty years to arrive from the burn received from the sun.

Light comes from the sun to us in a few minutes, for light travels 186,400 miles a second. So it shoots through to us in about eight and a quarter minutes. When we look at the sun, we see it not in the place where it actually is in the sky, but in the place where it was eight minutes before.

The sun ball sends out light and gives out heat in every direction possible. Only the least fraction of the sun's heat comes to the earth, but enough reaches here to keep every living thing on earth alive. It supports the plants and the trees and all the men and animals. It raises clouds and makes possible all the work that is done. What the sun does for the earth seems like magic, since we are so very far away from it. Because the sun is tremendously hot, it can give us heat at this great distance. If the rays of the sun were shut off from our atmosphere a few days, the air would soon be chilled and the earth frozen.

We know that the sun is about ninety-three million miles away. If it were only half as far away, we could set paper afire by putting it out in the sunshine. If our earth ever came as near to the sun as it is to the moon, the earth would melt and very soon would turn into vapor. We think the sun's heat is very great here

on the earth on a summer day, but it is forty-six thousand times greater at the sun's surface. There it would melt a layer of ice forty-one feet thick in one minute.

We cannot look long at the sun in a clear sky, for it

—*Lick Observatory*

The Sun with spots big enough to swallow the earth

is so brilliant that it hurts our eyes. It is better to look at it through smoked glass or when the atmosphere is very hazy. If we should look at it through a telescope,

we would find that it is covered with spots. There are dark spots to be seen upon it, some of which we may see with the naked eye in cloudy or smoky weather.

Some of these sun spots are so large that they seem to be great holes in the sun, so large that our whole world could drop into one of them and have a thousand miles to spare all around. Some astronomers say the spots are not holes but vast whirlpools. One remarkable thing about these spots is the fact that the sun has an especially bad attack of them about every eleven years. It is by watching the sun spots that we can tell how long it takes the sun to turn on its axis. It revolves once in about twenty-six days.

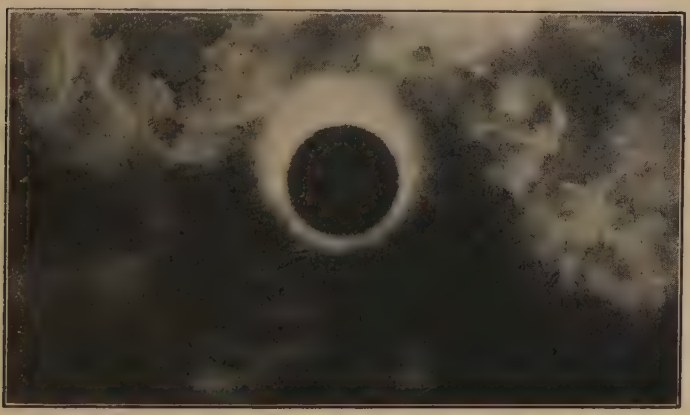
We know that there are tremendous explosions on the sun, for we can see the flames through the telescope when the moon is between us and the sun. The flames shoot out from twenty-five thousand to three hundred thousand miles.

The sun's surface seems to be a boiling ocean of white-hot metal vapors. This ocean of white-hot gas is constantly driven by great storms. Some terrible energy is streaming out from the sun and blowing its outer layers into gigantic hurricanes.

By using the spectroscope, we learn what elements there are in the sun—such elements as iron, copper, zinc, hydrogen, and helium. They are the same as those we find on the earth, but they are not in the same form as we know them here. The sun's heat is so intense that they are all turned to gases. There appear to be new elements on the sun that we have not yet

found on the earth. With our fine instruments one element was found on the sun thirty years before we found it here.

Suppose we wanted to make two balls—one to show the size of the sun and the other the earth. We should make the globe to represent the sun twenty-six feet in diameter, and the ball that stands for the earth about the size of a tennis ball. Travelers have been known to go around the world in eighty days, but it would take them nearly twenty-four years to go



Eclipse of the Sun

around the sun at the same rate. If the earth were to swell to the size of the sun and men were to grow in the same proportion, a man would be six hundred and twenty-five feet tall. He could stand at the side of the Washington Monument and look over the top of it.

One of the things about the sun that puzzles us a great deal is how its heat is kept up. There are

tens of thousands of acres of coal lands in the world. But if we should get all the coal together, how long do you think it would keep the heat of the sun? All this coal would supply the heat of the sun one ten-thousandth part of a second. We really do not know just how the sun's heat is produced. Some think that it is from radium on the sun. Some say that the breaking down of atoms gives out all the heat. Others think that the everlasting heat of the sun is due to its shrinking very slowly.

The time may come when the sun will use up all its fuel, and it will become frozen and lifeless like some of the planets that move around it. But this could not happen for so many million years that we do not need to feel alarmed about it.

The earth is pulling everything toward it by gravitation, as we know. Now the sun pulls very much harder than the earth, twenty-seven times as hard. For this reason, everything on the sun weighs twenty-seven times as much as it would here. A man of ordinary size would weigh more than two tons there. He would be so heavy that he could not walk. Suppose you find how much your baseball would weigh on the sun.

The sun pulls the earth as a magnet pulls a piece of iron. Our earth moves around in a circle or path, called its *orbit,* and the sun never lets us get away. There are seven other planets that are held captive by the sun and made to travel around it in regular paths. This seems like magic. Then when we think that our sun is only one of millions of stars, and

that they all may have planets moving about them, we can see how wonderful is the great universe.

Questions and Problems

1 How is the sun like a star? Is our sun a large star?
2 Illustrate the distance of the sun from us.
3 How far does light travel in a second?
4 What do scientists say of sun spots?
5 Compare the size of the sun and earth.
6 Is it not amazing that we get so much heat from the sun which is ninety-three million miles away? How is it explained?
7 What is a spectroscope? What is the earth's orbit?

CHAPTER VII

THE SUN'S FAMILY

THE Earth and several other world balls that move around the sun are called *planets.* Planets are not stars, because they do not shine by their own light. We can see the other planets only because the sun is shining on them, and they reflect the light to us. On an excursion to the sun we would pass only Venus and Mercury. They are the only two planets that are closer to the sun than the Earth.

The sun, we might say, has a family of eight children that get all their heat and light from him. They move around the parent each in a great circle. Some are close to the father sun, and some are far away. One of these eight children is our own world ball.

So let us say our Earth has seven sisters. This family of eight planets forms what is called the *solar system.* The sun is the center and is chief of the system, with the Earth and other planets moving around it. The daughters of the sun, or the planets, are called Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The same sun warms them all, and the same stars shine upon them all; but they differ much from one another, and each one is very interesting.

This family of eight planets are moving each in its own path, millions and millions of miles away from the sun, so that you might think they were going off into space to join some other sun; but they keep in

their paths year after year and come back to their places, and have done so no one knows how long. Astronomers can calculate just where each one will be a year or a hundred years from now, or where each one of them was a hundred years ago. Now close your eyes and see if you can imagine how the sun and his family look. Think of a bright sun and eight little faint specks moving around it all in the same direction.

MERCURY, A FIERY WORLD

Mercury is the baby of the great sun's family and is not much larger than our moon. We sometimes see Mercury as a bright star near the western horizon just after sunset. It is then an evening star. Some days later we see the same planet as a morning star before sunrise in the eastern sky. It swings around the sun, and we see it now on one side and then on the other, but we cannot see it except when the sun is hidden, for his glare is too bright. That is why Mercury can be seen only just before sunrise or after sunset. It follows or precedes the sun across our sky every day.

Mercury is the planet nearest to the sun. We should not call it near, for the distance is about thirty-six million miles. If a railroad could be built from Mercury to the sun, it would take a train going a mile a minute over sixty-eight years, or a man's lifetime, to go to the sun.

When we look at Mercury through the telescope, we see it has phases like our moon—quarter full, half full, and full. When it reaches the side of the sun nearest

to us, its dark side is toward us and we cannot see it, since the sun is shining on the side turned toward him. When Mercury gets around on the farther side of the sun, however, we see its full-moon shape.

Mercury is a smaller planet than the Earth, its diameter being three thousand miles, while the Earth's is nearly eight thousand miles. A man who weighs one hundred and fifty pounds here would weigh only about thirty-seven pounds on Mercury, as gravity varies according to the bulk of the planet.

The planets which are closer to the sun move around quicker than the others. Mercury goes around the sun four times while we are going around once. So eighty-eight days is the length of a year on Mercury. This planet gets more heat and light than any other members of the system, because the nearer we are to the fire, the warmer and brighter it is.

Through the telescope astronomers found certain marks on Mercury. By these they have proved that this planet always keeps the same face turned toward the sun, just as our moon always keeps the same face toward the Earth. From this we know there is perpetual day on one side of Mercury and perpetual night on the other.

The sun shines about seven times as hot on Mercury as on the Earth. The sunny side of the little planet is exposed all the time to this fierce glare of sunlight, making the heat above the boiling point. If there were ever oceans on that side, they have long since boiled away. But on the dark side, everything must be cold and frozen, two or three hundred degrees below the

freezing point. If anything lived on this dark, cold side, it would never get any light except from the stars.

It was not till after the telescope came into use that much could be known about Mercury. Then astronomers began to figure out its path and to foretell when it would pass between us and the sun. For years they worked on their theory, but the planet never appeared just when they said it would. It was always early or late, which showed that they had not yet solved the problem.

It was in 1627 that a great astronomer, named Kepler, predicted that on November 7 of that year Mercury would cross between us and the sun. Kepler said we could then see its dark little spot going across the bright sun's face. Nobody was sure that Kepler was right, so a man named Gassendi got ready to test Kepler's theory. He set his telescope and began to look on November the fifth. All day he watched. Again at sunrise on the sixth, he began his gaze at the sun, but Mercury was not seen on that day. Then came the seventh of November, when Kepler said it would surely pass at a certain hour; but when that hour came, Mercury was not yet visible. Five hours later the planet really came and passed across the sun's face. Kepler had missed the correct time by only five hours.

Astronomers were now able to correct their mistake and had Mercury's path marked out exactly. The planet does not move in a perfect circle, nor does it always move at the same rate. When Mercury is nearest the sun, it goes thirty-five miles a second, but

when farthest away only twenty-three miles a second. This is what made the problem so difficult.

Besides its motion, we know very little about Mercury. It is one of the planets that has no moon. It has an atmosphere that contains water vapor like that of the Earth, but we have never seen any clouds. If it has no clouds, then we know it has no rain or snow.

VENUS, THE EVENING STAR

Next to Mercury in distance from the sun comes Venus, which is the most brilliant of all the planets. It glitters in the sky like a pure diamond. Through the telescope, Venus shows all the phases or changes of the moon. Sometimes, like Mercury, it is a morning star and later an evening star. When the moon is not shining, Venus is so bright that it casts a shadow at night, and this planet may be seen with the unaided eye in full daylight.

Venus is only a little smaller than the Earth, and might be called the Earth's twin sister. It is about sixty-seven million miles from the sun, and goes around the sun once in about seven and a half months, or two hundred and twenty-five days. As it is nearer the sun than we are, Venus receives almost twice as much light and heat as the Earth, but only a third as much as Mercury.

Many astronomers think that, like Mercury, Venus always keeps the same face turned to the sun. Then it must have perpetual and frozen night on the side away from the sun, and perpetual and scorching day

on the side toward the sun. We are not sure about this, however.

Astronomers tell us that Venus has an atmosphere a little rarer than ours, and that the weather there is fearful beyond words. Violent windstorms blow continually between the hot and cold sides of the planet. This being so, Venus would be a very unhappy globe to live upon.

Venus showing crescent

The surface of Venus is so bright as to be difficult to study with a telescope. The light of the sun is reflected to us by such dense masses of cloud and dust, that it is almost impossible to trace any permanent markings on the planet and thus to find out how long it takes to rotate on its axis. Occasionally Venus passes between the Earth and the sun, giving us what astronomers call a "transit of Venus." The planet can be seen by the naked eye as a black spot on the

sun's face, crossing it from east to west. The last transit occurred in 1882, and the next is not due until June 8, 2004.

Except for the moon and an occasional comet, no other heavenly body comes so near the Earth as does Venus. Yet we know less about Venus than about Mars; the reason being that when Venus is closest to us, it is between us and the sun, and its dark face is turned toward us.

MARS, THE WAR PLANET

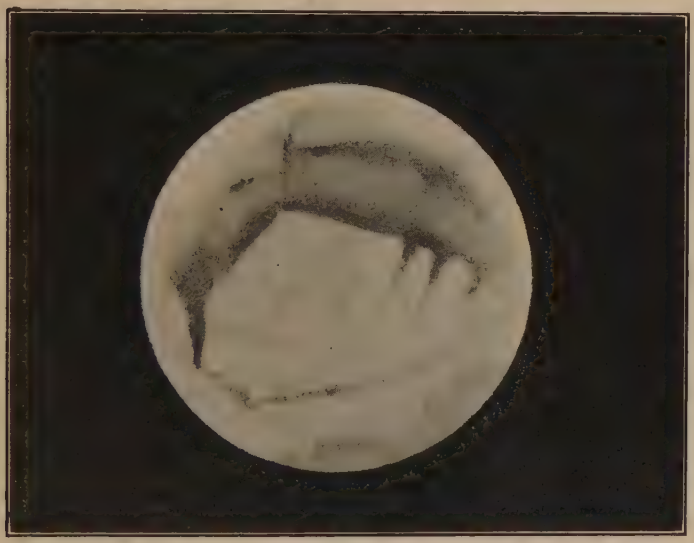
After Mercury and Venus in distance from the sun, is the Earth with its one frozen moon. Next we come to our neighbor, the planet, Mars. Mars is smaller than the Earth, being only forty-three hundred miles in diameter. The Earth would make seven planets the size of Mars.

Gravity on Mars is only two fifths of what it is here. So a boy who weighs eighty pounds here would weigh only thirty pounds there. But if he could jump five feet here, he could jump thirteen feet there.

In 1873 a new telescope with a 26-inch refractor was built at Washington. It was at that time the largest telescope in the world. A few years later (1877) Mars came round to its nearest point to the earth, and Professor Hall turned his big telescope on it. On August 11 he detected a minute speck of light near the planet, and a few days later he discovered it was a little moon passing around Mars; it moved very fast.

The next evening he discovered a second moon.

One of these tiny moons is six miles in diameter and the other seven miles. One makes its trips around Mars in about seven hours and the other in thirty hours. A day on Mars is about twenty-four and one half hours, so one moon goes around three times every



—*Lick Observatory*

Mars with its supposed canals

day and the other about once a day. The rapid one goes through all the changes from new moon to full moon in one night.

Mars never passes between us and the sun because it is farther from the sun than the Earth. So Mars does not have changes like our moon, but is always full.

A year on Mars is six hundred and ninety-seven

days, which is nearly two of our years. If you lived on Mars, you would be only half your age. Our neighbor has seasons like ours, but they are nearly twice as long. The winter season we should think would be bitterly cold because, owing to its greater distance from the sun, Mars receives less than half the light and heat that comes to the Earth. Yet Mars seems to have a milder climate than we should expect, because so far as we can judge, the water is never frozen except very near the poles. Clouds are rarely seen. In 1894 an area larger than Europe was hidden from our view. Whether or not it was raining, we cannot say. The screen may have been mist or a dust cloud. Astronomers say that Mars does not have such fierce storms and cyclones as we have here.

When nearest the Earth, Mars is thirty-five million miles away, and when observed with a telescope magnifying one thousand times, it is brought to a distance of about thirty-five thousand miles. It then appears only six or seven times as large as does our moon to the naked eye, and it is difficult to distinguish the details and markings. We can see two white, polar ice caps, which disappear in the summer. This truth proves the summer there is warm enough to melt all snow at the poles. We can see orange-colored regions which may be deserts, and blue-green areas which change to orange in the autumn and winter of Mars. These blue-green areas may be some kind of vegetation which fades in the fall.

The planet is covered with a network of fine lines which some astronomers have called *canals*. They

seem so straight as to make some believe they were built by intelligent beings. There are no mountains on Mars, the surface being surprisingly flat. The Martian sky is usually clear like that of a desert land, except that there is a haze about the poles just after the snow has melted. The planet also appears to have dust storms.

One of our leading astronomers feels sure that Mars is inhabited by beings of some sort or other, but whether they are like us or far different, nobody can say. This man thinks they are intelligent beings and have perhaps dug the great waterways on the planet.

Other astronomers, however, say they find no water vapor in the atmosphere of Mars. They think that as the atmosphere of Mars is certainly scanty, and the distance from the sun is so great, it may be too cold for fluid water to exist on the planet.

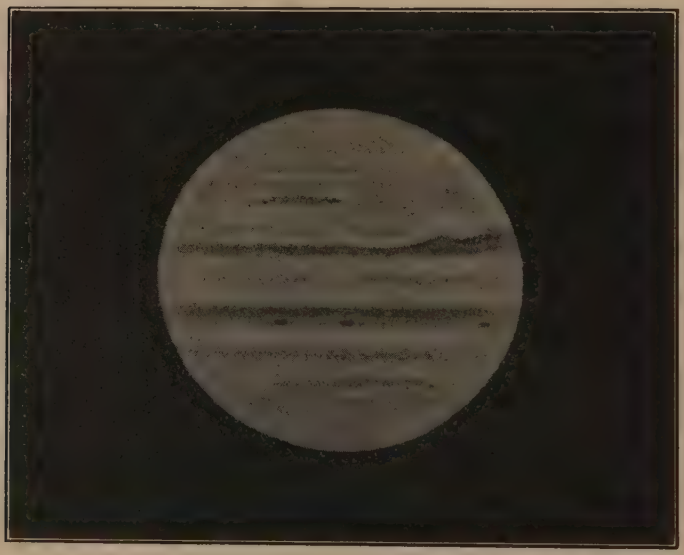
Some of these disputes may be settled when Mars next comes to its nearest point to the Earth. It is interesting to think that Mars is inhabited by intelligent beings, and that we may yet learn to communicate with them by some wireless code, and, in return, hear from them.

JUPITER, THE KING OF PLANETS

From Mars we come to Jupiter, which, next to Venus, is the brightest planet. It is larger than all the other planets put together, and is thirteen hundred times as large as the Earth. If we let a marble represent the size of the Earth, we should need a foot-

ball to stand for Jupiter. This planet is eleven times greater in diameter than the Earth, and five times farther from the sun.

Jupiter, unlike most of the planets, is brightest in the center. This leads astronomers to think Jupiter



Jupiter, the largest planet

may still be a hot ball—so hot as to increase the sunlight which it reflects. Its temperature is said to be above that of boiling water. The planet is concealed most of the time by clouds, but there are times when the clouds part and the central globe can be seen. The clouds appear to fly at a terrific speed. Great cyclones drive forward two hundred miles an hour and last seven weeks or more.

Jupiter receives too little heat from the sun to account for all that is going on there. Some think that the heat necessary to produce these changes must come from the planet itself. The colors of the changing clouds seen through the telescope are said to be remarkably beautiful.

While Jupiter seems a boiling planet, it is still young and may, in the course of millions of years, cool off so that plants and animals may come to live upon it. Jupiter revolves once in about ten hours, which is a day on that planet. The night lasts but five hours. Jupiter passes completely around the sun once in twelve years.

The most wonderful feature of Jupiter is its system of bright moons, four of which were seen by Galileo with a small telescope. The fifth moon was discovered by Professor Barnard from Mt. Hamilton in 1892. This last one is difficult to see, for it is only one hundred miles in diameter and is so close to its parent that it is lost in his glare.

A few years later two more moons were discovered from Mt. Hamilton by a photographic plate. Later still, in 1908, the eighth moon of Jupiter was discovered from Greenwich.

One having a telescope can enjoy watching the larger moons of Jupiter. They disappear behind the planet and come forth again on the other side. Then they pass in transit across Jupiter's face like little black dots.

By measuring the movement of Jupiter's moons, astronomers made a remarkable discovery. They

found out exactly how long it takes light to travel from Jupiter to us. So we now know that light travels

Jupiter

Showing changes in position of the four bright moons

186,400 miles a second. This fact has been a great aid to science in many ways.

SATURN, THE RINGED PLANET

Saturn is a beautiful object through the telescope, because it has ten moons and a wonderful system of rings. This planet, next to Jupiter in size, is a ball nine times as large as our Earth. It moves around the sun in twenty-nine of our years and revolves on its axis in about ten hours. If we look at Saturn with

Saturn with its wonderful rings

the naked eye, it appears like a bright star; but when seen through the telescope, it looks very different.

Instead of being a simple ball like Mars or Jupiter or Earth, Saturn is a ball surrounded by rings. These rings, which are less than one hundred miles thick, look solid; but when we examine them with a spectroscope, they are not solid at all. They are composed

of thousands and thousands of meteorites—pieces of iron and stone of all sorts and sizes, moving in circular formation around the ball of the planet. Each meteorite has its own path or orbit. The sun shines on this swarm of little balls and makes them bright.

Besides the thousands of little moons, Saturn has a family of ten larger moons that are farther away, just floating around in regular paths. Several of them are quite small.

As Saturn turns around on its axis once in ten hours, a day on that planet is about the same as a day on Jupiter, and only half as long as a day on the Earth. We cannot see very much of Saturn because of the thick layer of clouds. What is inside of this we do not know. Probably the interior of Saturn is hot because it is brighter in the center. We are told that there is no life on this planet.

URANUS

The planets that we have thus far read about are all bright enough to be seen easily. They were seen among the other stars many, many years ago. People thought them peculiar because they kept moving while the other stars did not move.

We learned that about one hundred and fifty years ago Herschel discovered Uranus. Herschel at first thought it was a comet, but in a few months it was proved to be a planet, located nineteen times as far from the sun as the Earth. Herschel, we learned, was given a pension for his good work, and so was allowed

to spend the rest of his life studying astronomy, while the government paid for his support.

Uranus has four moons, no one of which is half as large as our moon. It is not possible to see anything on the face of the planet, as we are looking through

Uranus and two of its satellites

endless clouds. Uranus is sixty-four times as large as the Earth and is probably hot like Jupiter. However, we cannot be certain about this.

NEPTUNE

Astronomers have figured out just where these different planets will be found in the future, because they know just how to calculate their paths. When Uranus

was discovered, astronomers figured just where it should be in the year 1800 and where it should be in 1840. When the year 1800 came, Uranus was not in the exact place where it was believed it should be. When the year 1820 came, it was not quite where it was expected then, but still a little farther away, and so on in 1830 and 1840.

Some unknown body or planet was thought to be pulling Uranus away from the place where it would naturally go. A bright young Englishman only twenty years old, named John Couch Adams, who was an excellent mathematician, set himself to the task of locating the unknown planet. After much hard work he sent a letter to the astronomer at Greenwich, telling him about how big it was and just where to look for it. This young man had succeeded in calculating the position of the unknown planet without a telescope, and he was right.

Adams's letter was not opened for some days, and meantime a French astronomer had the good fortune to discover the new planet. It was found just where young Adams said it was, but because of delay he lost the honor of being the discoverer. The new planet was called Neptune.

Thus Neptune was not discovered until 1846, less than one hundred years ago. It appears to be a very small globe, and in the telescope it looks greenish—not so yellow as Uranus, and not nearly so bright. It appears small because it is so far off, but the diameter is thirty-five thousand miles, more than four times the Earth's diameter.

Neptune moves around the sun in about one hundred and sixty-five years in a mammoth circle, a great distance from the sun. When we look at it through the telescope, we can see no marks upon its face. Pos-

Neptune and its Moon

sibly it is surrounded with an envelope of clouds. Probably the planet itself inside of the envelope is hot, and if this is true, it is not yet a fit place for anything to live. These things are probable, but we do not know them for certain. Neptune has one moon.

Questions and Problems

1 What is the difference between planets and stars? Name the planets.

2 Which planet excluding the earth is most interesting to you? Give reason.
3 What are the things you would like to remember about Mercury?
4 Why is it that though Venus comes closer to us than any other planet we know less about her than we do about Mars?
5 What do we know about Mars? Should you like to think Mars inhabited?
6 Tell of the marvels of Saturn.
7 Why could not Jupiter be inhabited?
8 To whom would you give the credit for discovering Neptune? Why?

Home experiment: From an almanac find the time of the year when the planets, Venus, Mars, Jupiter, and Saturn, may be seen as morning or evening stars, and try to locate them.

CHAPTER VIII

THE STARS ARE SUNS

THE stars are all suns and shine by their own light. Some of them appear very dim to us, because they are so very far off. If we were near them, they would be bright and hot like the sun. Only the sun looks large to us, and we receive its heat because it is near. The stars look small because they are so far away. We get no heat at all from the stars, though we do get a little light.

It is very hard for us to comprehend how very far away from us is the nearest star. The distance is so great that it has to be measured by the rate at which light travels, which is 186,400 miles per second. It requires light coming at this amazing speed about eight minutes to travel from the sun to the earth, but it requires more than four years for light to reach us from the nearest star. Most of the stars are too far away for astronomers to measure the distance, but you may be interested in learning that the light from the Pole Star which reaches your eye must have started on its journey shortly after the Civil War, while that from the Pleiades may have set forth before Columbus started on his great voyage.

Suppose you go out some night and look at the sky with the naked eye. Choose a small space and count the stars in it; then take a common opera glass and look again, counting the stars that you see in the same small space, and you will have many more. A

large telescope will show you a thousand times more than you are able to see with the opera glass.

The astronomers have counted all the stars that they can see. We do not know just how many others there are. We can see six thousand with the naked eye, but we cannot see them all at one time. With our largest telescope we see a hundred million stars.

In the universe is room for everything. We cannot imagine an end to space. All the stars that we see

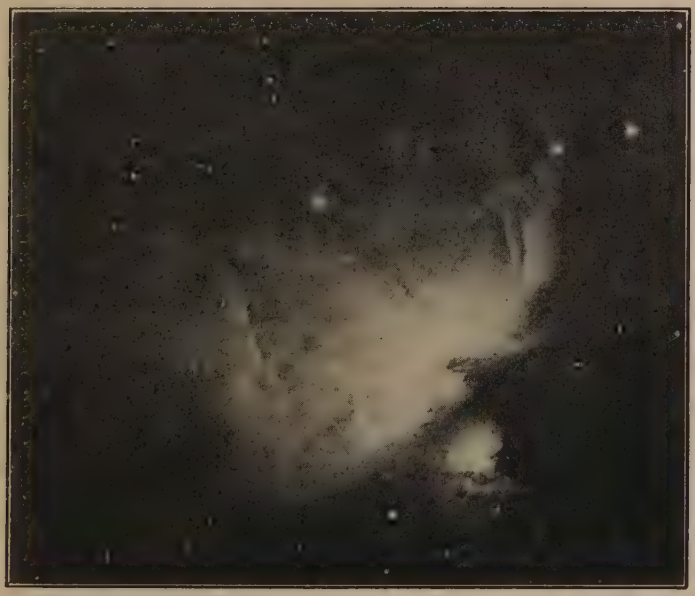
—*Lick Observatory*

The Milky Way, showing millions of stars

on a bright night are in endless space. Each of them is a sun very much like our own sun. It is supposed that many of them have planets moving around them just as the Earth and the other planets move about our sun. We are not certain that this is true, but why should it not be so? If each of the stars that can be seen had a family of eight planets, then there would

be eight hundred million planets. Very likely there are stars having only two or three planets, and there may be some that have none—childless stars, we might say.

If the stars have planets about them, the planets do not shine by the light of the stars. So it would be impossible for us to see them even with our most



—*Lick Observatory*

Orion, the most brilliant star cluster

powerful telescope. If we were standing on the star nearest to us, we could not see our Earth, because the Earth only reflects light, and it would be far too dim. Therefore, if you would like to do so, you may believe

that the other stars have planets about them, and that these planets have men upon them. No one can prove that you are wrong, and you cannot prove that you are right.

If our Earth stood still, the stars would seem always to keep in the same place in the sky; but, nevertheless, they are all moving through space just as our sun and his family are doing. The stars are so far away that although one of them should move a million miles a day, it would be years before our astronomers could detect a change of position. We are told that our sun and the planets are moving through space at the rate of eight hundred miles per minute.

Questions and Problems

1 The distance of the stars is measured in light years. Explain.
2 Do you think the stars have planets revolving about them? Why could we not see such planets?
3 How many stars may be seen by our largest telescopes?
4 Can you locate Polaris, the north star, by the Big Dipper?

CHAPTER IX

COMETS AND SHOOTING STARS

WE know that the Earth and her sister planets move around the sun in circles, or near circles, called *ellipses*. There are other bodies in the heavens which also swing around in great ellipses. They approach the sun at some part of their path, and then they move far, far away—farther than the most distant planets. These bodies are called *comets*.

The comet is a beautiful object with a head that sends off a very bright light. It has a flaring tail which grows fainter as it leaves the head. The tail extends from the side opposite to the sun. The head of the comet must be nearly twice as thick as our earth ball in order to be large enough for us to discover it with our telescopes. Some of the comet heads have been measured, and one is thirty-one times larger than the Earth. Another is one hundred and fifty times as thick as our Earth. Some of the tails are so long that they could reach from the Earth to the sun.

Some comets have regular courses. They appear and then disappear for several years and return. Astronomers have measured their courses and can tell when they will appear again. Halley's Comet comes back once in every seventy-six years. There are others that will not come back for a thousand years, or for many thousand years.

Another thing that we have found out about the comets is that they are not able to hold together. They break into pieces. Some of these pieces become cold

when they get out into space and harden into lumps. Sometimes these lumps, whirling in their own way, follow the same track as the comet. If the comet should break into many pieces, it would make a group of these lumps all going in the direction and in the same path about the sun.

Halley's Comet, to be seen again in 1986

The tails of comets are so thin that our Earth actually passed through one once, and no one but our astronomers knew anything about it.

As we have walked out in the evening we have all, at one time or another, seen a falling star. A falling star sometimes leaves a trail of light behind it, and we wonder which of the beautiful stars of heaven has

fallen. But astronomers tell us that no real star falls. What we saw was a lump of matter of which the world's comets are made. While it was following its own swift path around the sun, it got so close to our Earth path, that the Earth drew it down by gravity. So this bit of world stuff fell to Earth.

Brooks Comet and a Meteor Trail

It was just a cold, dark lump of stone or iron, too small for us to see until it reached our atmosphere. When it began passing through our air, which was thick enough to cause friction, the cold lump was raised to a white heat and burned up, just as a match scratched on sandpaper burns. When it began to

blaze, we saw it and said, "There is a shooting star." By the time it had come within twenty or thirty miles of the Earth, it was entirely consumed. Sometimes the lump is so big that it does not have time to burn up while passing through the hundred miles or more of our atmosphere, and what is left of it strikes the Earth with such force that it buries itself in the soil.

These lumps are called *meteorites*. If they strike the Earth, they are called *meteors*. We may see them in some of our museums. Strangely they have no new metals or elements with which we are unfamiliar. The elements are the same as we have on Earth, but they are sometimes combined differently. In the Yale museum there is a meteor weighing sixteen hundred pounds. It was fortunate that no man stood where this meteor struck the Earth.

If it were not for the air which wraps our globe like a great blanket and sets a friction fire to these meteors, and destroys them before they get to the Earth, we might all be pelted to death. Professor Newton tells us that in every twenty-four hours our world meets seven million of these shooting stars. Some of them are no larger than shot, and others weigh tons. But they generally burst into fragments and fall or burn without doing damage.

Questions and Problems

1 What is an ellipse?
2 What are comets? Do they return to our view?
3 What would happen if the Earth passed through the tail of a comet?
4 What are falling stars and why are they not dangerous?
5 What do we know of meteors?

CHAPTER X

THE STORY OF THE SEA

THE sea covers the greater part of the Earth's surface, but though it appears to separate great nations, it really binds them together. It is like a million water roads leading everywhere with no cost for upkeep. It invites all the people along its shores to launch their craft on its bosom and sail away to visit and trade with other nations.

The great surface of the sea seems about the same everywhere, but its floor is very uneven. It has mountains and plains like the continents. Here and there are great deeps like tremendous saucers. At other places are hills and valleys. On the ocean floor are mountains whose lofty summits rise to the surface of the sea and form islands such as the Hawaiian group.

We know that the average depth of the sea is about two and one half miles, but in a few places it is very deep indeed—over six miles. If the highest mountain in the world (Mount Everest, which is nearly six miles high) could be placed in this deepest place in the Pacific, the mountain top would still be more than a half-mile under the surface of the sea.

The sun shines hot on the broad waters of the ocean but its power affects only a thin layer on top, perhaps a hundred feet deep. This heated layer of ocean water travels in great currents like the Gulf Stream. The deeper waters of the oceans even near the equator never feel the sun's rays but remain near the freezing

point of fresh water from year to year. At the depth of a mile there is no sunlight whatever. There it is always winter and always dark.

The air presses upon our bodies with a weight of about fifteen pounds to the square inch at sea level. We are used to this air pressure and do not notice it. In the sea this pressure is doubled at a depth of thirty-five feet, and it increases at this rate for greater depths. In the great deeps off the Philippine Islands, a man would be squeezed and utterly crushed by a pressure of several tons per square inch.

The pressure near the ocean floor is so great that if you were to weight a piece of wood and lower it to a great depth and then pull it up again, it would no longer float, for it would have become water-logged. All the tiny wood cells and cavities would have burst and become filled with water.

We know that animals live at a depth of three miles and more, and we marvel how this can be. The bodies of animals down there are mostly filled with water and this saves them from being crushed. However, many of those animals contain some gases, for when they are captured in nets and drawn to the surface, this gas expands until the animal actually explodes. Its body is torn to shreds as it bursts.

Why is the sea salt, and where did the salt come from? The rain found it upon the land first and the rivers have carried it to the sea. When the water of the sea evaporates and rises in clouds again, it leaves the salt behind. There are about three and a half pounds of salt in every hundred pounds of sea

water. Salt makes the water of the oceans heavier than the fresh water of rivers and lakes. It is easier to swim in salt water than in fresh water.

In the far north the winter sea is covered with ice, which is heavier than fresh-water ice because of the salt. Still it is able to float and to bear the sleds of the Eskimos and the explorers. The salt ice sheet is broken by the tides into *pack ice,* which is often piled into mountains.

In the Arctic summer when the sun does not set, the ice plane breaks up into floe ice, which drifts southward until it melts. Icebergs which break off from the lower ends of glaciers also float southward in huge masses, or islands, often several miles in width. Bergs have been reported that were thirty miles long. Only about one sixth of the iceberg appears above the surface of the ocean. Large icebergs tower from one hundred to two hundred fifty feet above the sea. The largest ones are found in the Antarctic Ocean.

As the icebergs drift away from the poles toward warmer waters, they often invade the paths of ships, and in times of fog cause fearful collisions. The greatest disaster of this kind ever recorded was that of the *Titanic* on April 14, 1912. The *Titanic* was the largest ship in the world at the time. She was sailing on her maiden voyage from Southampton to New York with more than two thousand passengers and crew. Striking the iceberg without warning in the fog, she sank quickly. More than fifteen hundred lives were lost.

The life of the ocean is very interesting. There

is said to be far more living matter in the sea than there is in all the rest of the world. Sea water is full of millions of tiny plants, and fish live upon these and upon one another.

The largest sea animal is the whale, which is the giant of the animal world to-day. Its tail is so powerful that with a single blow it can destroy a large boat. Sperm whales and right whales may be from fifty to seventy feet long, and there are others still larger. The blue whale reaches a length of ninety feet with a weight approaching seventy tons. Very few are found these days except in the south seas.

The ancestors of whales, it is said, lived on land, for they still have slight traces of hind legs. They are warm-blooded animals and feed their babies from the breast as land mammals do. But ages ago, whales changed their home—moving from the land to the sea. The whale is suited to live in the ocean. He is shaped like a submarine boat, with a tail turned into a powerful paddle. He has flippers on his sides to keep him balanced and layers of fat or oil under the skin called blubber, which furnish heat and make the huge body light and buoyant.

The whale has blow-holes with valves on the top of his head so as to get air easily when he comes to the surface. He has an enormous chest and lungs that take in a great quantity of air at one time. When he comes up to breathe, he generally stays on the surface about two minutes, during which he blows several times and then disappears.

The right whale may remain under water for half

an hour or more, which is a wonderful performance for an air-breathing animal. On a sea voyage you may frequently see whales "spouting." They are only blowing out the used-up air from their lungs which carries up a little spray of water with it.

The whale's eyes are no larger than those of an ox, but he can see well under the water. When in search of food he swims with mouth open. The water is forced out through the whalebone, leaving the catch in the mouth.

One of the odd-looking birds of the ocean is the penguin, which is well fitted for sea life. It is found in the cold regions of the antarctic circle. Penguins cannot fly. Their wings have been changed into swimming flippers which they use like oars. With the aid of the flippers they can dive to a depth of thirty feet.

Penguins spend no more time on land than is necessary for sleeping and for rearing their young. Their food consists of the small creatures of the sea, which they catch by diving, often to great depths. They use their feet not as paddles but as rudders to guide them. Under their skin is a layer of fat which like blubber helps them to withstand the icy water in which they live.

Some gather stones and sticks for a kind of nest; others make no nest whatever. A single egg is laid and both father and mother bird share in sitting upon it. When hatched, the mother guards it with great care, keeping it with her for a year. Though they cannot fly, the penguins make long voyages along the antarctic shores every year, swimming like the seal.

There are hundreds of interesting sea birds, like the pelicans, gulls, the petrels, and cormorants, but we have no space to tell about them here.

The strangest haunts of life are in the deep sea, by which is meant the floor of the deepest part of the

"A funny old bird is the pelican"

ocean and the layers of dark water near the floor. Life is found six miles below the surface where the water pressure is enormous—more than six thousand pounds to the square inch. It is very cold there—always about zero. It is also absolutely dark except for the fitful gleams of some fishes which, like fireflies, give out light of their own. It is too deep and dark for any plants to grow because plants need light, but no depth, it seems, is too great for animal life.

As there are no plants at this depth, the animals must feed upon one another. The struggle to live is

keen. The stomachs of some of the fishes stretch amazingly, so they may swallow objects larger than themselves. When a whale or a porpoise meets death in the ocean and sinks to the bottom, there is a great feast by millions of living things till the monster is devoured.

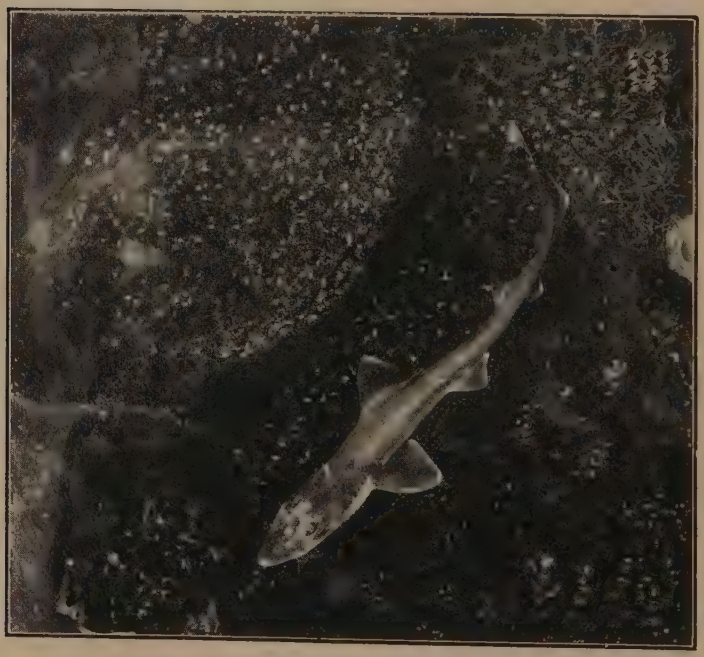
The sea swarms with strange and curious animals prowling about in the dark, some with long feelers and some with long limbs like stilts. Then there are the cuttlefishes and true fishes stealing along. Cer-

Flying Fish—Method of escape from enemies

tain kinds here are blind. They depend upon great feelers to get about and capture food.

In the blackness of the deep sea many animals produce their own lights. This light may attract other fishes wanted for food. But some deep-sea fishes have very large eyes so as to see in the dim light that they

themselves make. Some of these animals have been brought up by dredges at night, and, it is said, "they gave off flashes of light, besides which the twenty torches used for working light were pale." Some of these animals were carried into the laboratory where the lights were turned out. These creatures threw out brilliant jets of fire which changed from red to orange. Others shed green lights.



Luminous shark swimming in kelp

Many fishes have these light-giving spots. Some are called lantern fishes. They shine starlike in the

black deep. One kind has a luminous snout like the headlight of an engine. One cuttlefish has about twenty of these luminous spots. Another fish has two bright plates just under its eyes. One of these gives off red light and the other green. It is thought that the fish has control over them and turns its lamps on or off when it pleases.

Some deep-sea fishes have rows of light spots, and as they swim they resemble lighted steamboats or railroad trains at night.

Remora or sucking fish attaches itself to sharks by a disk on top of its head. Does no harm but gets a free ride

Several kinds of fishes like eels and rays have the power of generating electricity which they use to protect themselves. In some cases fishes can discharge enough electricity to paralyze a much larger animal

than the fish itself. It is believed too that these fishes use electricity to capture their prey.

One animal that divides its time between the water and the shore is the seal. It not only comes on shore to rear its young, but for resting purposes at any time. The shape of the seal and its smooth fur make swimming easy by avoiding friction with the water.

As the seal glides along, the hind legs are thrown backward beside the short tail to form a propeller. Its nostrils can be closed under water; the sensitive whisker hairs are used as feelers is the dark sea. The

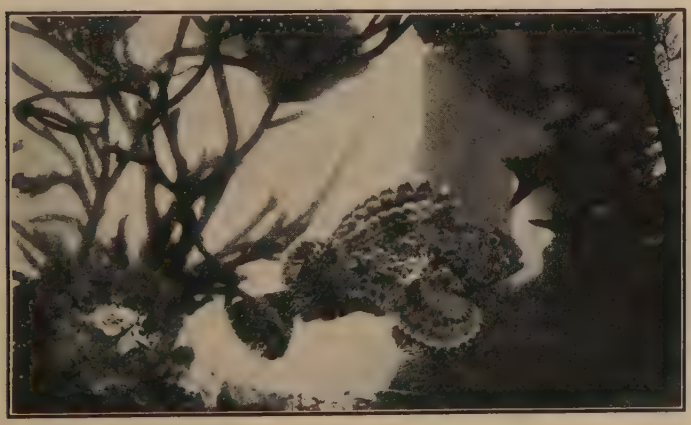
Feeding Old Ben, the seal

seal has blubber to buoy it up and to furnish heat, and this same blubber is a store of food upon which it lives when the weather is too stormy for fishing.

The common seal can swim ten miles an hour. The

seal pup often takes to the water the day of its birth, but it needs long rests on shore.

There are many sea birds that spend part of their time ashore, such as gulls, terns, cormorants, sandpipers, and curlews. Then there are many seashore fishes, which have strange names as well as queer habits. There are also crabs and lobsters and shrimps, and many other shellfish. Starfish and sea urchins cling to rocks and stones near the shore. Near Catalina and other islands of the Pacific Ocean we may study sea life through glass-bottomed boats.



Sculpin, a queer fish eaten by larger fishes

Many years ago treasure ships went to the bottom of the ocean, and their riches were lost forever. In shallow seas a diving bell came into use some years ago to reach the treasures. One of the early uses of this invention occurred in 1683, when William Phipps offered to search a rich Spanish wreck near an island

in the West Indies. Charles II of England gave him a ship to use for this purpose. He made the attempt, but returned unsuccessful and in great poverty.

Still Phipps said he believed it could be done. He asked the king for another ship and was refused. Then Phipps went among his friends to get the money for another trial. Many laughed at him, but finally enough money was subscribed, and five years after his first attempt he set out again. By using a diving bell, he brought up from the wreck, forty feet below, nearly a million dollars, which made him and all those who aided him wealthy.

A diving bell is a strong, heavy vessel of wood or metal, made perfectly air and water tight at the top and sides, but open at the bottom. By lowering it carefully into the water the air in it cannot escape, and therefore the bell will not fill with water. Thus a man may descend in this bell, breathing the air in it, and work for several hours. When the air becomes bad, fresh air is pumped into it through a tube. When the bell is down thirty feet, the pressure of the water compresses the air into one half its former volume, and so the bell becomes half full of water. Thus the bell cannot be used in very deep water. Diving suits are now made in which divers have gone down nearly three hundred feet and recovered the cargoes of shipwrecked vessels. Submarines to-day play about in the depths of the ocean.

It is well known that the sea is the cheapest of all highways, for there is no cost for upkeep as there is for railroads, and no upstream pull as in rivers. The

ocean steamer can strike off in any direction. Every nation desires as many seaports as possible.

As bays and gulfs enable ships to go far inland for their cargoes, a country with a deeply indented coast-line has the advantage of cheap transportation. Many wars have been fought by nations like Russia, which has few seaports, to get more harbors on the sea. One of the causes of the World War was Germany's desire for more sea coast and better harbors.

Though the sea covers about three fourths of the world's surface, it furnishes, except fish, a very small part of man's food. However, it was the fish of the sea that first led man to sail the ocean, and in searching for good fishing places, the sailors found new lands far beyond the almost boundless sea.

Questions and Problems

1 How do we know anything about the floor of the sea?
2 Read what you can find about diving bells.
3 Why is it always cold and dark in the ocean deeps?
4 What use is made of the salt of sea water?
5 Why do deep-sea animals explode when brought to the surface?
6 What would happen if an air-tight bag were filled with air and sent up fifty miles from the earth? Why?
7 In what respect are the sea and the atmosphere alike?
8 Compare the penguin and the goose.

Home experiment: Make other questions on this chapter to test the thinking and reading of your classmates.

CHAPTER XI

THE EARTH'S ATMOSPHERE

WE are all living at the bottom of a great ocean of air which extends many miles above our heads.

We have at last learned to travel in this ocean of air. The first airplane to stay in the air was built by Langley in 1896. His ideas were later improved by the Wright brothers. Orville Wright first flew for twelve seconds on December 17, 1903.

This early machine was fitted with an engine of only sixteen horsepower and flew about thirty-five miles an hour. To-day we have aircraft fitted with engines having over fifteen hundred horse power, and flying at speeds of nearly five miles per minute.

Twenty years after the first flight by the Wright brothers very long flights were made. The first of these was that of Alcock and Brown across the Atlantic, the journey being made in just sixteen hours against the normal period of six days for boat traveling. Then in 1923 Kelly and Macready made the first non-stop flight of twenty-seven hours across the United States from New York to San Diego, a distance of twenty-seven hundred miles. In 1924 a flight was made around the world.

The difficulty with long flights has been that the lift of an airplane is limited, and if most of the weight is taken up by fuel, very few passengers and very little cargo can be carried. With short flights larger loads

can be transported, because less fuel is necessary. Modern aircraft can now carry loads upward of twenty-four tons, fly at two hundred miles an hour, cover distances of over two thousand miles without stopping, and rise to heights greater than Mount Everest (29,000 ft.).

Airmen have conquered every handicap of the atmosphere but fog, and there is promise of overcoming that. On several occasions when the wind has been so rough that steamers were stormbound in the harbors, aircrafts have safely made the journey between London and Paris. When the country is fog bound, however, flying becomes dangerous, because the pilot is unable to see the ground and cannot choose a safe spot for landing. He may crash into a building or a tree before he can see the nature of the ground.

The ocean of air may yet become as well known and as much used for travel as the oceans of water.

As we ascend in an airplane or climb a mountain from the level of the seashore, the air becomes less dense, until at a great height it becomes so thin that it cannot support life. At a height of twenty miles the air is very thin indeed.

The highest point to which any bird can fly is about five miles. The condor, we are told, can struggle up to that height, but most small birds and insects which are carried up by airplanes or balloons become insensible much below that level.

The greatest height which any mountain climber has ever reached is about five miles. In 1920 men had flown in airplanes to a height of over six miles, while

balloons with men in them had ascended about seven miles, but the men suffered very greatly. In some cases they became unconscious before this height was reached. In other cases where oxygen was carried for breathing, the chief discomfort was from cold.

Small balloons containing only recording instruments have risen as high as twenty-two miles. At this height the air is still dense enough to carry the balloon.

When "shooting stars" enter the earth's atmosphere, they are suddenly chilled, for the temperature of outer space is thought to be about four hundred and fifty degrees below zero, Fahrenheit. In passing through the atmosphere, as we have read, meteors are heated by friction with the air, and when they become red-hot they may be seen. The height at which they begin to glow has been calculated in some cases, and found to be nearly two hundred miles above sea level. This shows that the atmosphere is much more than two hundred miles deep, for the meteors must have come a long distance through the thin upper air before becoming red-hot by friction with it.

The air itself is a mixture of gases, the chief of which, in the lower layers, are nitrogen and oxygen; much smaller quantities of carbon dioxide and water vapor are also present, together with a few other gases. In the upper layers of the atmosphere, hydrogen and helium are both believed to be present.

Of late a great deal of study has been given to the air at different levels. Balloons are used in this study. One kind of balloon which is used is set free and rises till it bursts. Then the instrument that it carries falls

to the earth. A light bamboo framework around the instrument keeps it from injury when it strikes the ground. The remnant of the balloon also acts as a parachute to make the instrument descend slowly. In this way the records made high in the air usually reach the ground in good order. If they escape, a notice is attached to the instrument, saying that the finder will be given a reward by turning the instrument in at any post-office. Records have been obtained of the temperature and pressure of the air higher than fourteen miles above the earth's surface.

These records have a very curious story to tell us. In days gone by, it was believed that the higher we ascend the colder it becomes, until the extreme cold of outer space is finally reached. But this is not so. The temperature does fall off with height until a certain level is reached, but above this level the temperature remains practically unaltered, as far as our balloons have yet gone. This level in our latitude is about seven miles; at the equator it is ten miles, and at the poles about five miles.

All the teeming life on our planet is rendered possible by the thin zone or layer of air about three miles deep at the equator and thinning out northward and southward till it ends at the ground level in the neighborhood of the arctic and antarctic circles. Of all the extent of our atmosphere, this thin zone is all that has a temperature above freezing point.

We all know that when the wind blows, it has power to drive ships or to blow down trees and buildings; but for a long time no one knew that the air has

weight, or that it presses down upon the earth.

Galileo was one of the first men to have a correct idea about air pressure. He had a suction pump which would not work when the water was low in the well. He sent for a mechanic to repair it, but was told that the pump was in good condition, and that no suction pump would lift water much over twenty-five feet. Why this was true the mechanic could not explain. Galileo believed the reason was that the air pressure was not great enough to raise it any higher.

Galileo set one of his pupils, named Torricelli, to work on this problem. Torricelli proved that Galileo's idea about air pressure was correct. He showed that at sea level it will support a column of water about thirty-four feet high. If we had a suction pump that would create a perfect vacuum, it might raise water that high; but no suction pumps can make a perfect vacuum.

Torricelli took a glass tube about three feet long, open at one end and closed at the other. He filled it with mercury, which is a very heavy liquid, being 13.6 times as heavy as water. Then, holding his thumb over the open end, he inverted it in a cup of mercury. He was careful not to remove his thumb till the lower end of the tube was well below the level of the mercury in the cup. The column of mercury in the tube dropped till the top of it was about thirty inches above the level of the mercury in the cup, and remained there. You would have expected the mercury to run down into the cup, but it was held up by the air pressure on the mercury in the cup. Thus Torricelli taught us to

measure air pressure by a column of mercury in an instrument called a *barometer.*

Blaise Pascal, a Frenchman who lived about the same time as Torricelli, discovered how to tell the elevation of a place by using a barometer. He and some friends took with them a barometer and climbed a mountain. They found that, as they ascended, the column of mercury slowly fell in the tube. Then when they came down the mountain, the mercury arose again toward the thirty-inch level. Thus they proved that the higher we ascend from sea level, the lower is the air pressure.

Questions and Problems

1 Consult reference books for more facts about Langley's airplane.
2 What difficulties are met in long-distance flight?
3 Why can aviators fly higher than any bird?
4 What element in the air do animals need? Plants?
5 How is the ocean like the atmosphere?
6 What is a vacuum?
7 Explain, if you can, how the barometer works. Can you also explain a thermometer?

Home experiment: Set a short piece of candle upright on a piece of cardboard. Light the candle and cover it over with an inverted drinking glass. Watch results.

CHAPTER XII

THE STORY OF ANIMALS

THE animal life of the land includes the mammals, birds, and reptiles. A bird is a warm-blooded animal with feathers that lays eggs from which its young are hatched. The reptiles are cold-blooded animals with scales or a bony shell, and the mammals are the warm-blooded creatures of the earth whose young are nourished by the milk of the mother. All land mammals are covered with hair and breathe with lungs. Except man, the land mammals all have four feet, save that those of the monkeys are more like hands.

There are thousands of species of mammals on the earth, both wild and tame. Man became civilized only so fast as he made use of the animals. It was largely by mastering the wild beast that he made progress. With the strength and power of the animals which he domesticated and taught to work and do his bidding, he conquered the soil and provided himself with food and clothing.

The cud chewers and hoofed animals, such as the cattle, horse, and sheep, have been most easily domesticated. No domestic animals eat flesh except the dog and cat.

Even the half-civilized people of the world are dependent upon some beast of burden. The Eskimo has the dog to drag his burdens over the snow and ice. The Lapp has the reindeer to pull his sled and to furnish him with milk. The Indians of South America

use the gentle llama. The people of middle Asia have the yak, and the men of the desert the camel; while the people of India have trained the clumsy elephant to lift logs, draw burdens, and carry men through the jungles on hunting trips.

Both wild and domestic animals have furnished man with warm clothing so that he may dwell in cold climates. For many years wool, silk, or skins were the chief source of men's clothing. It was only a few hundred years ago that cotton came into use. Leather has always furnished a protection for the feet, and nothing has been found to take its place. Our forefathers and the Indians used deer skin for moccasins, and to-day we use calfskin and sheepskin.

The larger part of the plants that grow on the earth are not suited for the food of man, but the cud-chewing animals thrive on grass and herbage, and turn it into milk, from which our staples of butter and cheese are made. Cattle, sheep, and swine provide us with most of our meat. Beef, mutton, and pork, along with fowl, constitute a large part of our diet. Cattle and swine are raised on the grassy plains of our country and are shipped to stockyards in Chicago, St. Louis, or Kansas City, where every part of the animal is made into useful products. The hair is used in the plaster of our houses, the hoofs are used for glue, the hides for leather, and the bones for fertilizer for the soil.

We do not know when the horse was first tamed. In early days we know he was wild and lived in the open country. We know that the horse lived in the time of the cave man, because we find pictures of him

scratched in stones and sand drifts. The horse was smaller than he is now. Some were hardly two feet high, about the size of a small pony. We still find the small horse in cold, bleak lands. The pony of the Shetland Islands is the best known small horse.

Horses were first used by kings, nobles, and warriors to ride upon. The Greeks and Romans hitched them to their chariots. The farmer for many ages did his work with the slow plow-ox until at last the swifter moving horse was hitched to the plow and wagon.

When the first white men came to America, they found no horses. Later they brought these animals over with them, and many laughable stories are told of the surprise of the Indians when they saw men mounted on strange beasts.

Some of the horses escaped or were deserted when their white masters were killed by the Indians. In time, herds of wild horses were found on the plains of America. These were captured and tamed by the Indians and the white people of later days.

Years of careful breeding have produced the strong draft horse, the slim-necked trotter, and the many beautiful beasts of burden in use to-day. The horse is very faithful and intelligent. If trained when a colt, he can be easily broken to harness and will follow commands. Some horses give good service for twenty-five years.

In the days of the cave man there were also wild cattle. The cave man at first killed them for meat. Perhaps he kept the calves for pets. Then he tamed

them and kept them for their milk. While the milk was being carried in skin bags, the cream became jarred into butter; this was a great discovery for mankind. Then we find early man becoming a herder. He hitched oxen to loads and made them beasts of burden. With a crude plow they were used to turn the soil for crops. To-day we have certain breeds of cattle especially raised for their milk, and other larger kinds that are killed for beef.

Sheepskins made fine, warm clothing for man in early times. On the plains of Asia to-day there are still wild sheep that are killed for their flesh and wool. Sheep are raised in great flocks. They can live on rough hillsides and mountain tops where other domestic animals would starve. They supply the world with wool. The skins are used for clothing and shoes.

Our hogs of to-day came from the fierce wild boars that roamed years ago through the forests of Europe, living on nuts and rooting in the earth with their long snouts. They were dangerous beasts to hunt with only clubs and bows and arrows. We wonder how this fierce animal was tamed and made into the fat and lazy animal of the pigsty.

Our chickens probably came from the wild jungle fowl of India. Early man used to snare the large wild birds for food and robbed their nests of eggs. When he settled down to herding flocks, he tamed this wild fowl, and to-day we have the contented hens that stay quietly in coops and lay eggs all through the year.

When our forefathers came to America, wild turkeys furnished them food until crops could be raised.

Turkeys have never been thoroughly tamed, for they love to wander. We still have wild ducks and geese on our lakes and ponds.

Three hundred years ago in the days of the Indian, our forests and plains were alive with wild beasts. Bison, deer and beaver, wildcats and bear, roamed everywhere. The first settlers came for the skins of wild beasts, trapping and hunting being the first industries.

The haunts of the wild animals of the earth are shrinking very rapidly. Forty years ago Theodore Roosevelt and other valiant hunters trailed the cougar and the grizzly in the Rocky Mountains, but now the grizzly is hardly to be found wild within the limits of the United States. He was once the terror of the mountains, for a bullet could not easily pierce his furry hide, and a blow from the great animal's paw was likely to be fatal.

The bison and antelope that roamed our plains are no longer found wild, but are confined to the national parks. Over the trails where trappers hunted the beaver there are now automobile roads. Seldom do we see any of the large wild creatures except in a few uninhabited regions. Even the deer and the black bear and the wildcat are found only in the mountain wilds.

Hunters and men of science who want skins for museums must go to Africa or South America or Alaska. Photographers who want pictures of wild life for the moving-picture screen must go to foreign countries. In the jungles there may still be found elephants, lions, tigers, and leopards, and the

fast-disappearing hippopotamus and rhinoceros.

The hundreds of wild animals living to-day are roughly classed in a few interesting groups which have common habits. The apes or monkeys are the highest order of animals and stand next to man. Some of the gorillas of Africa are nearly as large as a man. They have no tails, and are the only monkeys that stand erect without being taught. The gorilla spends part of its time on the ground, but is very shy and is seldom seen in captivity.

The chimpanzees and orang-outangs are the most intelligent apes. These are Old World monkeys, and most of them are tailless. They are more easily taught than the smaller long-tailed monkeys of Mexico and South America. The howlers and spider monkeys of this group have prehensile tails with which they grasp branches to support themselves as they swing from bough to bough.

Marmosets and lemurs are harmless, stupid little monkeys with long, soft, furry tails in which they wrap themselves when sleeping. They are as gentle as rabbits and about as intelligent. Monkeys carry their young on their backs or in their arms, and they do so many half-human things that they are credited with more intelligence than they really possess.

The cat family embraces the lion, the tiger, and the leopard of the Old World; the jaguar, cougar, lynx, and ocelot of America. These are all flesh-eating animals. They have sly, stealthy habits, creeping through the brush and leaping upon their prey from above or behind. All are more or less afraid of man,

but they are easily trapped. They have powerful jaws, sharp teeth, and terrible claws with which to tear their victims.

The jaguar is the South American tiger. It has spots somewhat like the leopard, but it is a larger beast with a big head, short tail, and black rosettes on its golden yellow hide. It kills pigs and cattle and even horses and deer, but is afraid of man.

The cougar is found in the Rocky Mountains, and is a thin-bodied, flat-sided animal that hides in the daytime and hunts at night. The bobcat is a common short-tailed, tree-climbing lynx. The Canadian lynx is larger. The lynx catches chickens, rabbits, and other small animals, but is a treacherous fellow and cannot be trusted even when captured and tamed.

The dog family includes wolves, coyotes, and foxes. All these animals have mean, sneaking traits. They frequently hunt in packs, and kill animals much larger than themselves. They are seldom trapped, and the coyote is said to be so wise that he knows when a man has a gun. The wolf is a cruel beast that eats his own brothers if they are wounded.

The marten family includes weasels, otters, minks, ferrets, and skunks. These are small, flesh-eating animals. The wolverine and the badger are larger animals belonging to this group. The wolverine is about the size of a large dog and is the hungriest member of the family. If a wolverine gets into a camp, it will destroy everything, whether it can eat it or not.

The bear family ranges from the white polar bear of the cold regions to the grizzly, the big brown bear,

and the small black bear. The raccoon is called the "little brother to the bear." The black bear climbs trees, but the grizzly lives on the ground. In the colder regions bears hibernate in winter. They find a den in the rocks or in a hollow log, and sleep until spring.

Several other smaller animals also hibernate. The squirrel comes out on sunny days and eats from its store of nuts, but the woodchuck and raccoon sleep all winter. The heavy sleeper, like the hedgehog, chooses a hole as soon as winter comes, rolls himself into a tight ball, and goes to sleep for the entire season. Since he does not move, he does not rapidly use up his reserve fat or energy. Even his breathing is slow, and his heart beats feebly.

Many animals are burrowers. The badger, the woodchuck, and the anteater burrow in the ground where they hide their young and are safe from their enemies. We have seen the holes of the prairie dog and the gopher. These animals are not fighters, so they protect themselves by hiding.

The shrews and moles are little mouselike fellows that are seldom seen above ground. In farming countries underneath the long dead grass which covers the top soil, cutworms and wireworms deposit their larvæ. Here little moles police the ground. The mole is a furry little beast with no neck and no external ears or eyes. He looks like a short-tailed mouse. The shrew has a neck and external ears. Since moles seldom see daylight, their vision is very slight.

Bats are strange, wing-handed creatures found among the caves and rocks. They fly about at night,

and in the daytime hang head downward from the ceilings of dark caves.

The squirrel families range from the big gray squirrel of the tree tops and the smaller red squirrel to the tiny ground squirrels and rock squirrels that live on nuts and roots.

Among the hoofed animals of the wild are the deer, —swift-footed, shy creatures,—the reindeer and caribou with their wide-spreading horns, the antelope, and the mule deer. The giraffe is found in Africa. Its long neck allows it to browse in the tree tops. In South America is the tapir with its hog-like body, and in Mexico the peccary, which is a sort of wild hog. All are browsing beasts living on grass and herbage.

In South America, Africa, and Australia are found the anteaters. They are toothless mammals that root up the earth with their long snouts and feed upon ants, which they lap up with long, sticky tongues. The giant anteater is the largest of these. Among them is the armadillo with his bony shell, into which he disappears like a turtle and rolls away from his enemies. The slowest moving animal in the jungle is the sloth. It hangs to the limbs of trees and is easily knocked off and killed with a stick, for it offers no resistance.

The pouched animals are the kangaroo and opossum. The young are very small when born and are carried in a pouch under the mother's body until well grown. The kangaroo snatches up her baby, pokes him head first into the pouch, and runs away with great leaps on her strong hind legs. If the danger becomes too

great and she is likely to be overtaken, she sometimes throws the youngster into the grass and runs on alone.

Two strange, egg-laying animals of Australia are the duckbill and echidna. The duckbill has a bill and feet like a duck, a body like a mole, and like a turtle lays soft-shelled eggs in a burrow in the ground. While its nest is on land, it lives and eats in the water.

The elephant is the largest land animal and the only one with a trunk. It is found in India and Africa. The end of the trunk acts as a sensitive finger tip, picking up very small things and carrying food to the elephant's mouth. The rhinoceros and hippopotamus are other huge beasts. They have the same dark, thick, hairless hide as the elephant and both are herb eaters, but the hippopotamus lives chiefly in the water. The rhinoceros has a horn on his nose; some of them have two horns.

The lion, tiger, and leopard are the Old World members of the cat family. They are powerful, prowling beasts with cat-like habits, and are found in the jungles of Asia and Africa.

Rabbits and hares are found the world over, varying from the powerful jackrabbit to the gentle cottontail of our gardens.

Many of the wild animals prowl at night and sleep hidden away in the daytime. Even in cities small animals creep about in gardens or through deserted buildings at night. Rats and mice, weasels and skunks, squirrels and rabbits, are our close neighbors. Hundreds of species of insects, worms, and reptiles

are on the land. Living creatures are all about us, dependent upon us for their lives.

Man must constantly fight to prevent the animal and insect world from taking his crops; for the birds steal fruit, mice eat the roots of alfalfa, and coyotes and foxes rob the hen roosts of the farmers. Still he will always find a way in which they serve him. On the whole, he receives more help than harm from his four-footed friends, and to-day the study of animal life is one of the most interesting chapters in the book of nature.

Questions and Problems

1 What differences are there between mammals and birds? Between birds and reptiles?
2 What animal has been most helpful to man? Give reasons for your choice.
3 How do the domestic animals of to-day differ from those of ancient times? How has this improvement been achieved?
4 Do you believe in game preserves where wild animals are protected? Why?
5 How does the bear hibernate? Why does it not starve?
6 What animals, do you think, are best provided for getting their food? Which ones are best protected against enemies? Against cold and heat?

CHAPTER XIII

THE STORY OF THE BIRDS

NEXT to the green trees and the plants that furnish our food, and the animals that we have domesticated, a place of friendship must be given to the winged neighbors of the air. Birds guard our homes and gardens and provide us with music and companionship. What would we do without them?

It is said that we may go all over the world, and except in parts of the great deserts we shall have birds for companions. On the mountain ridges are found the grouse and the mountain blue jay. In the plains where nothing but cactus and sagebrush flourish are the sage grouse and the magpie. In the far cold north is the snowy ptarmigan, and on the bleak, icy shores of the antarctic the skua gull and the penguin.

Our seashores are guarded and kept clean by the gulls and pelicans. Even far out on the broad ocean where the gulls no longer follow, we find the stormy petrel. Everywhere are our winged friends not only able to care for themselves but able to render assistance to man.

The Indian killed birds for food. He used the feathers to wing his arrows and to adorn his clothing. Our early forefathers, as we know, lived on the meat of the wild turkey. The early cave man hunted birds' eggs and killed birds for food.

Man has learned to take the feathers of our domestic birds without taking their lives. He has taught them

to produce eggs the year round for food. But best of all, he has learned to protect the wild birds, since he has discovered how much they benefit him by eating millions of insects which would destroy crops of fruit and grain.

There was a time not long ago when we studied birds by making a collection of their eggs and of their skins. Then we found that we were destroying life to no purpose; for of what use is a stuffed bird or an empty eggshell except as a specimen in a museum?

For years the Audubon societies have been working to protect bird life. Now we know that we may study birds much better with a camera than with a snare, and far better with a field glass than with a gun.

With very little effort a person may know well forty birds and their habits; while real attention to the subject will give him, we are told, the power to identify a hundred twenty-five birds and will put him in the class of real bird students.

In the temperate and torrid zones are the perchers, or birds who live in trees. They are our loveliest songsters and our most active workers and helpers. In the torrid zone are many brilliant-colored birds of the parrot family. Most of them have coarse voices and are lazy because an abundance of food is always at hand.

In the temperate zones are the smaller birds of plainer plumage. Among them are a few bright-colored songsters: the wild golden canary; bright blue beauties like the bluebird, the bunting, and the jay; the brilliant-hued scarlet tanager, the gaudy cardinal,

and bright-splotched woodpeckers. But the greater number of the songsters have neutral colors of brown and olive green that help them to hide from enemies.

These birds of the middle zones have tuneful voices. We all know the cheering lilt of the robin and the flute-like notes of the thrushes and larks and bobolinks. We marvel at the variety in the songs of the catbird, the thrasher, and the mocking birds. From early morning till the sun goes down, we can hear the varying chirrup and musical notes of other songsters. They keep us in good cheer while they are eating caterpillars, insects, weed seeds, and even some of the small animals that threaten our crops.

Birds need a great deal of food because they are so active. They eat all the time they are not sleeping or caring for their young. One flicker was found that had in his stomach five thousand ants; a night hawk ate at one time sixty grasshoppers; and a bobwhite ate at a single meal seventeen hundred weed seeds. This alone would prove that the farmers do well to protect the birds.

Gene Stratton-Porter believed that if every form of bird life were swept from the earth, man would not long survive. "Naturalists and scientists agree that life on this planet would be impossible without the protection afforded us by the birds which destroy winged pests, bugs, worms, larvæ, and lice.

"Wild geese, ducks, loons, coots, gulls, and grebes feed in flocks. They keep the lakes from being overcrowded with fish, and they eat countless larvæ and worms along the shore.

"Cranes, herons, and bitterns stalk around the swampy shore line keeping down the frog population and eating lizards, soft turtles, grubs, and worms.

"Over the fields and open country go flocks of quail, cleaning up fallen weed seeds in the fence corners and snapping up grasshoppers and other insects here and there. They are helped in all this work by woodcocks, snipe, and prairie chickens.

"In the clover fields and meadows the larks, with the assistance of bobolink and ovenbird, search out wireworms and cutworms and clean the earth of every visible bug and insect. In gardens and dooryards the robin is a hunter of earthworms and injurious insects.

"Sparrows and finches eat weed seed and countless bugs and worms. Catbirds destroy worms, lice, moths, and insect eggs. The rose-breasted grosbeak eats the potato beetle. The orchard oriole and the cuckoo destroy the tent caterpillar by the thousands. Martins and swallows search the air with open mouths, taking millions of gnats, mosquitoes, and flies.

"Even the warbler family does great service. With their bright eyes and pointed beaks these tiny birds search under and over the foliage of vines, bushes, orchards, and giant forest trees, hunting out millions and billions of insect eggs, larvæ, plant lice, and newly hatched caterpillars."

The golden eagle catches in its talons mice, rats and rabbits, and skins them for its young; but as soon as the baby eagles can leave the nest, they are taught to kill their prey. The bald eagle and osprey are fishing birds. Hawks and owls kill grasshoppers, mice and moles.

The gannet lives on fish. It soars to a great height, then drops to the water like a plummet, stabbing with its long straight beak the fish swimming near the surface. The pelican lives on the coast and fills his great pouch with fish. Pelicans are said to form in a line and wade through shallow water until they have a quantity of fish cornered, when they scoop them up with their great beaks and store them in their throat pouches. They also fly above the water, darting down with a great splash for their prey.

The cormorant fishes in a different manner. It pursues its prey under water, turning and twisting about until it seizes the fish with its hooked beak. Then it comes to the surface, tosses the fish into the air, catches it again as it falls, and swallows it. The Chinese train cormorants to fish for them. They tie a collar around the birds' necks so they cannot swallow their prizes.

The bird has nothing to take the place of a hand unless it is his beak. The parrot has a sharp, curved beak that will bite wood and crack hard nutshells. The kingfisher's beak breaks the bones of the fish, and the seed eaters crush the hardest seeds with their sharp-edged bills. The humming birds reach into the hearts of the flowers with their long beaks. Storks and cranes use their beaks to fish in the mud for frogs and reptiles.

Every bird has feathers, and nothing that is not a bird can show any trace of them. The whole body of the bird is fitted to the habit of flying. We have long envied the bird his power to fly. In fact it was the

Cockatoo, a cousin to the parrot, but a poor teacher

birds that taught us to build our airplanes after the shape of their wings and bodies. The birds' wings serve as planes and propellers, for they have both lifting and driving power. The tail is the rudder and helps to steer. It also acts as a brake when the bird alights. Some birds like the birds of prey soar and remain in the air a long time with motionless wings. They can sail in a spiral to a great height. Others dart like swallows. Some birds walk on the ground, while others hop.

Birds, like aviators, can attain a certain speed in the body of air in which they fly, but we must remember that their speed measured from the ground may be far different. There is a "ground speed" and an "air speed." A bird may be flying fifty miles per hour in a twenty-mile-per-hour wind. It might seem from the ground to be going seventy miles per hour or only thirty miles per hour, depending on whether it is flying with the wind or against it. In either case its "air speed" remains fifty miles per hour.

Carrier Pigeons bear messages one thousand miles without a stop

Aviators have measured the air speed of certain birds, and have found some that can fly one hundred miles an hour. Carrier pigeons have been known to

make a mile a minute, while ducks go from forty to fifty-six miles an hour.

Birds have been seen flying three miles high, though they seldom are seen above one mile. Most bird flight is within half a mile of the ground.

Some birds, like the ostrich and emu, are tall with small wings and very long legs. They have never used their wings and have not the power of flight. They use their wings to balance their bodies as they run at great speed across open country. When attacked by enemies, they use their legs to kick with great force. The soft, hair-like feathers of the ostrich make the beautiful plumes of commerce.

The penguins have lost the use of their wings except as flippers to help them make their way in the water. These birds are wonderful swimmers and dive under the water like seals. They go hundreds of miles over the trackless sea of the south to rear their young. There in the snow and ice they are perfectly at home.

Most birds cannot brave cold weather, but migrate to warmer climes to spend the winter. In the spring they return to their old haunts. These long journeys are possible because the bird has a sense of direction that shows it the way. A tiny humming bird flies hundreds of miles through the air with nothing to guide it but this homing instinct. Birds' legs have been marked with aluminum rings, and many facts of bird migration have been proved by observing birds so marked. It is certain that some return year after year to the same neighborhood and sometimes to the same nest. Birds have been taken from their nests and car-

ried in cages hundreds of miles away from regions where they live, and they have returned.

The beautiful tanager that nests in our spruces in the summer spends his winter in South America. The robins fly away to the warm southland. In the spring many birds stop here and there as they are making their way to the northern pines to nest.

In the fall we hear the squawk of wild geese and see the leader going straight south toward the warmer waters. Before they started there was a battle on the pond to see which gander would lead the flock.

The carrier pigeon gives the best example of the homing instinct. When it is far from home it flies, like the bee, high in the air and returns to its nest in the most direct line possible.

Birds are wonderful weavers. A study of their nests fills us with admiration. The oriole hangs her nest from the swaying branches, but it is fastened so securely that the wind seldom tears it loose. The chimney swift cements its home firmly to the side of the chimney with mud. The humming bird makes a tiny cup of a nest with cobwebs, down, and the saliva from her own mouth.

The nests are so carefully hidden and guarded that we must hunt well for them. Only a few confiding birds nest under our very eyes. Hundreds of sticks and grasses are gathered for a simple nest. Some birds make several nests in a summer and raise two or three broods of young.

By learning a dozen new birds each spring, we may make ourselves not only bird students, but their pro-

tectors; for no one who watches these little creatures can overcome the desire to guard them.

Questions and Problems

1 Name some birds that are scavengers. Should they be protected?
2 What are the most useful birds? What birds should be destroyed?
3 Tell how birds differ in their ways of getting food. In fighting their enemies.
4 How many birds can you identify in the out of doors?
5 Have a contest in the making of bird boxes.
6 What birds are protected by law in your state? Why?
7 Tell of your observations of some certain pair of nesting birds or some other experience with birds.

CHAPTER XIV

JOHN JAMES AUDUBON

ONE of the first and greatest bird lovers was Audubon.

At the age of twelve Audubon's father, the son of a poor fisherman living in France, set out to make his fortune. As he had heard from his father much about life at sea, he decided to become a sailor. After many years upon the sea, he was made commander of a small ship in the French navy.

Captain Audubon often visited America, and it was in Louisiana that his famous son, John James Audubon, was born. The little lad was soon taken back to France, where he spent his boyhood happily. When he could get away from school, which in those days was not very interesting, Audubon spent much time in the woods watching birds and gathering their nests.

His father, on returning from a voyage, found his son was missing the benefits of an education. So he sent John James away to school. Among his studies in the new school the lad had some drawing lessons under a celebrated painter. He learned to draw well and to sketch from nature.

When Audubon was seventeen, his father wished him to become a soldier under Napoleon. But as he had no taste for fighting, his father sent him to Pennsylvania to look after his farm. Audubon spent much time in the woods and fields hunting and fishing. He drew careful sketches of two hundred kinds of birds.

After a time Audubon was married and tried his hand at business, but did not succeed. He loved the outdoor life and was still keenly interested in birds. He eagerly studied the habits of all the birds and animals found in the woods about him.

His father, at his death, had deposited with a merchant seventeen thousand dollars to be given to his son, but Audubon never accepted a cent of it. He gave his share of his father's estate in France to his sister, Rosa.

Audubon tried business again, and again he failed. Next he turned to painting portraits for a living. For a time he was successful as curator of a museum in Cincinnati, where he opened a drawing school; but he was not satisfied with that.

In October, 1820, Audubon started on an expedition through the southern states in search of bird specimens, for his love and chief interest was in his feathered friends. At Natchez he was in need of shoes and had no money. So he went to a cobbler shop and offered to make a portrait of the shoemaker and his wife in return for a new pair of shoes for himself and a pair for a companion who was also penniless. The offer was accepted, and the two went on their way newly shod.

At New Orleans Audubon tried in vain for employment. He secured a few orders for portraits, which relieved his needs for a while. He also taught drawing and finally sent for his family. They began life there on forty-two dollars. In order to help educate the

children, Mrs. Audubon took a position as governess. Audubon was downhearted because he could not earn money enough for his family. He set out for Natchez by boat, paying his way by a crayon portrait of the captain and his wife.

John James Audubon

After many hard experiences Audubon reached Philadelphia, where he hoped to obtain help to complete his book on birds. He did not succeed, and we soon find him in New York, trying to make money to

complete his work. Failing here, Audubon started back home, living on bread and milk on the way.

When he reached home, he found his wife had succeeded better than he. She had earned three thousand dollars, which she generously gave to him to aid in the publication of his book, "Birds of America."

Audubon was encouraged, and he now made a new resolve to attain the great wish of his life. He taught a dancing class of sixty men and women, and made two thousand dollars more.

At the age of forty-six the tide of fortune seemed to turn in his favor, and he sailed for England, where he hoped to get aid to put out his book on birds. He exhibited his pictures in Liverpool and received five hundred dollars. Other cities were glad to pay to see his exhibit. He wrote to his wife, saying: "My success borders on the miraculous. My book is to be published in fine style."

Audubon next went to Paris, where he met and enjoyed the famous scientist, Cuvier. The king of France subscribed for six copies of his "Birds of America," which gave Audubon great joy. In May, 1829, he returned to America, full of delight at seeing his family again. During the next three months he hunted for birds and animals to enrich his books.

Again we find him in England hard at work. He was made a Fellow of the Royal Society of London—a great honor. At last he was able to say, "I have balanced my account with the book, 'Birds of America,' and the whole business is really wonderful; forty

thousand dollars have passed through my hands for the first volume."

Audubon crossed the Atlantic several times more, but after his great work, "Birds of America," was published, he made his home on the banks of the Hud-

Audubon's home, New York City

son. He was now known and honored by learned men everywhere. He had found many kinds of birds unknown before, and he had pictured very truthfully the appearance and habits of all the beautiful birds of our land.

So it is not at all strange that thousands of boys

and girls of America delight in joining Audubon societies and in following the great leader in a kindly study of bird life. Young bird lovers everywhere are doing a splendid work in feeding and protecting our feathered friends.

Questions and Problems

1 Read any books on Audubon you can find.

2 Each time Audubon entered business he failed. Would you therefore say that his life was a failure? Why or why not? What constitutes a successful life?

3 Compare Audubon with Goodyear or other inventors in the matter of discouragements or obstacles to be overcome.

4 If you have not already done so, organize an Audubon bird club in your school.

Home experiment: Arise some morning at daylight and make a trip to the woods to observe the birds. Write up an account of your trip.

CHAPTER XV

PLANTS AND HOW THEY GROW

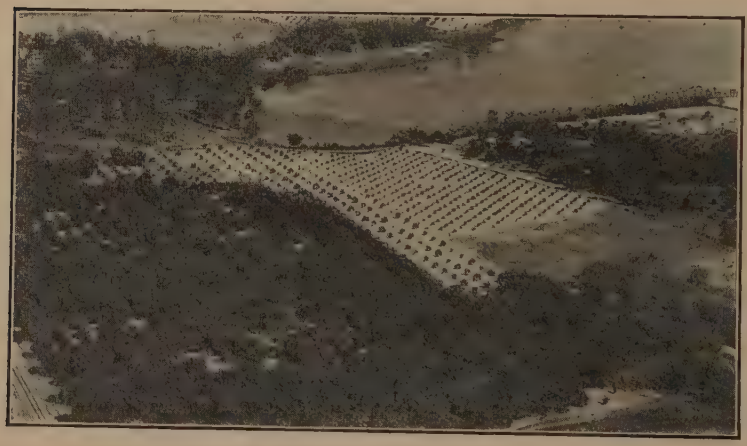
SINCE men and animals live largely on plants and farmers are kept busy growing crops to feed the world, we want to know more about how plants grow and produce seed. We may easily see what the animals about us eat and drink, but it is not so easy to learn just how plants eat and grow and bear fruit.

Plants need food, water, and air just as animals do. They also need warmth and light. The plant has different parts—a stem, roots, leaves, and flowers. It divides its work among these parts. The roots of the plants have their work, and it is different from that of the stem and leaves.

Let us first look at the roots. Pull up a radish from the garden, and you notice that the upper part of the tap root is large and round; it is stored full of food. It grows smaller and smaller toward the end. All along this tap root are tiny rootlets, with root hairs branching off from them. These root hairs cover only the tips of the smallest rootlets, but they extend out in all directions. They are very close together, for often there are as many as thirty thousand to one square inch. They are not young roots, because they never grow larger. They are only tiny little hollow tubes which contain sap. They have no pores or holes for water to enter, but it easily soaks through their thin walls. Thus these root hairs drink in the soil water which contains many of the plant foods; and the sap carries this watery food up along the

larger roots and stem to the leaves. Here the sunshine helps to make the plant food ready to build up the stem, leaves, and the fruit of the plant.

The larger roots do not take plant food from the soil. Their work is to hold the plant firmly in its place in spite of storms and heavy rains. When a plant is taken up to be transplanted, most of the small rootlets with their many long hairs are broken off. Perhaps



Orange Grove at Orlando, Ormond Beach, Florida

you can now understand why a plant is so likely to wilt when it is transplanted.

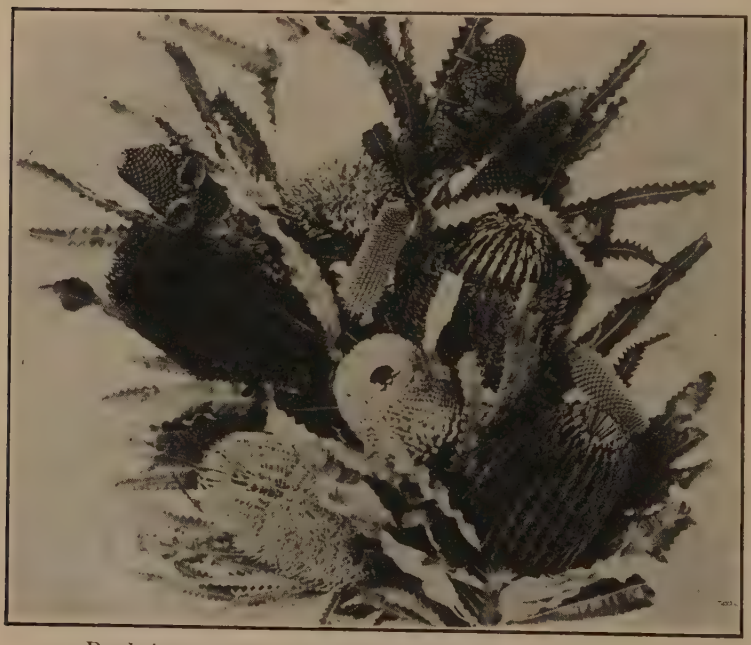
The stem, or trunk, of the plant bears the leaves and holds them up in the air and sunshine. It carries the watery plant foods from the roots up through the outer wood layer to the leaves. The food materials, or starch and sugar from the leaves, pass down under the bark to the part where they are needed to enlarge the plant.

But more interesting than the roots or stem are the leaves. They serve as so many stomachs where the plant food is digested and made ready for use. The chief work of the leaves is to make the plant foods over into starch and sugar. They take carbon dioxide from the air and combine it with the other food which

Plants grown by electric light

comes to the leaves through the root hairs, forming starch and sugar. The leaves also give off to the air all the water that is not needed by the plants. If the leaves, as they often do on very hot days, give off more moisture than the roots supply, the plant wilts—the leaves droop—in order to prevent further evaporation.

The starch and sugar made by the leaves is either stored up for food or used at once to build plant tissue. When enough has been stored, the plant begins to flower. The flower is sometimes beautiful like the apple blossom, but often, as in the wheat or oats, it is not showy.



Banksia flowers, Australia—a honey-bearing plant

The flower of the plants has a very important work to do because it contains the parts which create the fruit. The fruit contains the seeds from which new plants may be grown. If the flower fails to do its work, there will be no fruit, no seeds, and no new

plant, unless a new plant can be started from a slip or cutting of the old plant.

The flowers of different plants differ very much, but they usually have two parts. One is the "pistil," or mother part, which contains the ovule, or seed germ. This ovule will not grow into seed unless it receives

Mushrooms—Some are edible, others poisonous

some pollen or yellow dust that grows on another part called the "stamen." The seed itself contains a germ, a tiny baby plant, all tucked under a good cover with food enough for it to live on until it can send out rootlets into the ground.

Every plant must have its flowers with their stamens and pistils, but the stamens and pistils are not always together in the same flower. Examine a corn-

stalk as it grows. The tassel is the stamen, with its yellow dust, or pollen; and the ear is the pistil. If the pollen does not fall from the tassel on the silks of the ear and thus fertilize the ear, there will not be a grain of corn on the cob.

The corn is only one of many plants that have their male and female flowers separate. Such plants depend partly upon the wind to carry the pollen from the flower to the pistil where the new seed is to grow. Some plants depend upon insects to carry the pollen for them. These plants have bright-colored flowers that the insects can easily see. They also secrete a sweet food, or nectar, to reward the insects for their trouble. They hold out bright red and yellow and blue petals, and say to the insects, "Here you can get good honey."

Some plants depend upon insects that fly only at night to carry their pollen. These plants do not have bright flowers, because colors cannot be seen well in the darkness. They have white flowers; and to aid the insects in finding them, they have a strong, sweet odor that guides their friends. The insects come from far and near for the sweets. They brush against the stamens and get covered with yellow pollen dust. Away they go to other flowers, leaving some of this pollen on every plant they touch. When they go in deep for the honey, they leave pollen on the pistil just where it is needed.

Plants bear the strongest and best fruit and seed when the pollen has been brought to them from another plant. In a cornfield the ears on one stalk may receive

pollen from its own tassel and from a dozen others standing near. Sometimes when a farmer wants corn for seed, he goes about a certain part of his corn lot before the silks come out and cuts off the tassels of all the poor stalks. In this way he allows the ears to receive pollen from only the strongest plants.

A large head of cabbage

There are thousands of different kinds of plants in the world. Perhaps there was a time when there were very few plants. But as they spread over the earth, they found different kinds of homes. Some seeds were gradually carried into cold regions, and others into hot places; some found wet spots, and others came into desert regions. Some found homes on high

rough mountain tops where the storms raged about them, while others fell into low, shady nooks where they were protected.

As the plants were slowly carried into such different kinds of homes, they kept fighting for life and food. Often many plants were struggling for air and sunshine on the same little spot; and only those that proved good fighters lived. Slowly but surely many of these plants changed to meet their new surroundings and became unlike their early parents and even unlike their close kin. Each one set to work to protect itself and get its own food, and thus it slowly developed new parts, new ways of growing, and new ways of fighting for food. Only the strongest plants lived to spread their seed. In this way the world came to be covered with multitudes of different plants.

It is interesting to study the habits of different plants and how they grow and spread their kind. One of the important things that the farmer wishes to know about them is how they scatter their seed, because many weeds grow and fight for life where the farmer does not want them.

Some plants, like the coconut, grow their seed in a hard shell which is waterproof, so that they can float on streams and rivers to new homes. The seeds of the maple and ash trees have wings, and on these they sail away across the fields wherever the wind will carry them. The dandelion seed has a queer little balloon by which the wind carries it to some faraway home. Then we know the burdocks and other burrs that catch in our clothes or fasten themselves on

Giant parsnips

passing animals and hold tight for a long ride to fall at last and begin to grow in a new region. Any boy or girl who will examine the seeds of plants and do a little thinking will discover many interesting and wonderful secrets about their different habits.

Man has chosen certain plants that furnish food for

him and his flocks, and these he tries to help to good homes where they will grow and bring forth their harvest of grain or fruit. He spreads and sows these plants in different ways. He sows the seed of the common grains or cereals and covers them with earth. Sweet potatoes are grown from slips or plants; Irish

Asparagus beds

potatoes from the "eyes" of the potato; grapevines from cuttings or twigs clipped from the vine. Sugar cane is grown by planting a short piece of the stalk.

Many plants do not come true from seed, and man has learned to grow them by grafting or budding. A bud or graft twig is taken from one plant and so carefully put upon another of the same family that it will grow as part of the plant. And the strange thing

about it is that it will produce its own kind of fruit, and not the kind of fruit of the plant on which it is grafted. There is no end to the wonderful things man is learning to do with plants.

Questions and Problems

1 What is the use of root hairs?
2 Where is the sap changed to plant food?
3 Why do plants wilt when they are transplanted?
4 Where does the plant get carbon?
5 Examine some flowers to find the pistil or seed-bearing part and the stamens that furnish the pollen.
6 How do insects aid plants?
7 How do some plants scatter their seeds?

CHAPTER XVI

BURBANK, THE PLANT WIZARD

LUTHER BURBANK is well known to the world as the "plant wizard." He was his father's thirteenth child and was born on a farm in Massachusetts on March 7, 1849. His mother was very fond of flowers. In addition to the work she had in caring for a large family, she always kept her home surrounded with blossoms.

Luther, as a very small child, loved flowers. His sisters said they could always quiet him when he was a baby by putting a flower in his hand. He grew to be a frail, shy lad. He was afraid of strangers, but interested in all they had to say. In the busy world in which his family lived, Luther learned to use the saw and hammer, as well as to till the soil. He read the best books and studied a great deal.

When he was quite a young man, he had a sunstroke which affected his health for a time. He studied medicine for a year, and the acquaintance with biology which his study gave him was a great help to him afterward in his work with plants. About this time his father died, and he had to give up his medical course; so he decided to become a nurseryman and to grow young trees for the farmers' orchards.

Burbank got hold of Darwin's book, "Animals and Plants under Domestication," and began to improve his vegetables and seeds. He found a way to raise sweet corn for market earlier than any one else, and he

developed a new kind of potato called the "Burbank potato." The rights to this he sold to a wealthy man.

Two of his brothers had gone to California, and Burbank knew that if he wanted to work at developing new plants the year round, this was the place to which he should go. He therefore sold his little farm in Massachusetts and started across the continent with very little money but a great deal of ambition. It took him many days to cross the country. When he reached California, he had only a few books, a little clothing, and ten Burbank potatoes.

The first year in California Burbank barely made a living. He worked as a carpenter and helped in a greenhouse. He became ill from the dampness of the greenhouse and was unable to work for some time. It was five years before he had enough money to do the thing he had set out to do. Then with only a thousand dollars he started his nursery.

In 1881 a wealthy banker of San Francisco asked him if he could have twenty thousand prune trees ready to plant that fall. At first Burbank thought it would be impossible, but he knew this was a great opportunity; so he said he would try.

He knew that almond seedlings would grow much faster than prunes, so he decided to grow the almonds and graft prunes to them. He planted the almond seeds in coarse sand, and by June the prune seedling buds were ready to graft. In order not to kill the almond seedlings, he let the young tops die very gradually after the grafting was done. By December first he had almost the required number of young trees—

enough to satisfy his customer; but, best of all, he had made a name for himself as a nurseryman.

In good time Burbank had his nursery making money enough to carry itself so that he had his own time to experiment. Then began the development of the many new fruits, vegetables, and flowers that he has produced for the world.

We can tell of only a few of the things he has done; but these will give us an idea of how new plants are produced, and of some of the remarkable ways of plant life which he made use of in his experiments.

We have learned that every perfect flower has sepals, petals, stamens, and a pistil. The sepals are the outer leaves of the blossom. They are usually green but not always so. The bright-colored parts of the flower are the petals. Inside are the stamens, each of which bears on its stalk a little box of yellow powder, called the pollen.

At the heart of the blossom is the pistil where the baby plant is to grow, and on the top of the pistil is the stigma. When the pollen falls upon the stigma, it fertilizes or gives life to the baby seed which grows in the pistil. No seed will develop in the flower unless the stigma receives the pollen.

We know that bees of one kind or another are the great distributors of pollen in orchards and gardens. The fruit trees put forth their blossoms, which have perfume to attract the bees. There is a dispute among scientists as to whether it is the color or the scent that attracts the bee, but we know that the bee flies many miles in a straight line from his hive to the flowers.

We are inclined to think he must have a very fine sense of smell as well as a sixth sense, which is the sense of direction. There is no question that the color of the flower also attracts the bee.

"I should think the bees buzzing around from one flower to another would mix everything up," said some one. "Daisies would be crossed with poppies, and carnations with geraniums."

"But the bee is a wise harvester," is the answer. "If he starts out to make clover honey in the morning, he gathers nothing but clover nectar all day. He goes from flower to flower, but always to flowers of the same kind."

While some flowers attract bees, others attract butterflies and humming birds. Plants with deep flowers like those of the honeysuckle give up their nectar only to birds or insects with long beaks.

Some flowers can be crossed with those of a different kind, but there are many blossoms which cannot be intercrossed. There are different reasons for this. The pollen grains of some flowers are too large to reach the pistils of others. Many plants bloom at different times. The stamens of some flowers open earlier than the pistils, and when the bee has sucked the honey and taken the pollen to other flowers, then the pistil opens and he returns to bring the pollen from another flower of the same kind to pollinate the first one.

If a white daisy is pollinated by a yellow daisy, the new blossoms will not be the same; but if it receives pollen from a white daisy, the seed will reproduce

white flowers. When the white and yellow flowers are mixed, we say the flowers are crossed, and in time some of the flowers will be white and some yellow, or perhaps they will be white mixed with yellow.

Burbank works a great deal at cross-fertilization. He takes a fruit blossom and a fine sharp knife. On his watch crystal he gathers the pollen from a blos-

Burbank among his flowers

som. He cuts away the petals and the anthers of the flower he wishes to pollinate so the bees will not be called to it to undo his work. Then he carefully shakes some of the pollen on the stigma of the flower he wishes to fertilize. He tags this blossom and watches it carefully. The seeds from it he plants the next

season and again cross-fertilizes. It may take many years to grow the plant or flower that has just the qualities he wants.

At his farm at Santa Rosa, California, Burbank works away. Besides the bees he has many other helpers. Workmen are busy preparing the soil, planting and trimming and spraying to kill pests. Precious

Burbank's lilies regale

seed pods are protected by having paper sacks tied over them. There are more than two thousand new experiments going on all at once.

Mr. Burbank does the selecting. He ties a white string around the stem of the plant which has a quality he wants to preserve. Perhaps he fixes a stake with a double cross marked on it, which is his *O. K.* sign.

When the fruit is ripe, he is very busy. It is photographed, and a complete written record of all its qualities is made to compare with its record of the year before to see what progress it has made.

This wonderful care and experimenting has produced some things that seem miracles. Burbank has taken the seeds from the grape, the stones from the plum, the thorns from the blackberry, and the spines from the cactus. He has changed the color of the calla lily and the hue of the poppy. He has given fragrance to flowers that had no scent before. Besides creating new fruits, he has greatly improved the size, flavor, and bearing qualities of other fruits and vegetables in wide use to-day.

Questions and Problems

1 Suppose you wished to develop an early variety of sweet corn; how would you go about it?

2 How did Burbank grow his prune trees more quickly to meet the order?

3 How can flowers be crossed?

4 What fruits have you tasted or what flowers have you seen that were created or improved by Burbank?

Home experiment: Gather the flowering parts from trees, garden plants, and weeds, and see if you can discover the pistil that bears the new seeds, and the stamens that bear the pollen to give life to the seeds.

CHAPTER XVII

BURBANK CREATES NEW PLANTS

SOME one asked Mr. Burbank, "Do you know just what you want to get when you begin to experiment?"

"Experiments cost too much to do them haphazard," replied Burbank. "I have a picture in my mind of the flower or the fruit which I wish to produce, just as the architect has a picture of the building he wants to build."

Mr. Burbank wanted to grow an early cherry—one that would be ready to ship weeks ahead of any other kind. It was to be large in size, beautiful in color, and of good flavor. The stem had to be short to aid in shipping, and the tree that bore it had to be proof against frost and very productive. He knew just what he wanted. Could he develop such a cherry tree?

He studied cherry trees of every variety. In his orchard he found some that had ripe fruit a few days earlier than the others. He found some trees that produced more fruit than others. He found other trees that had more perfect fruit. Taking flowers from a cherry tree that had borne the earliest fruit, he pollinated the flowers of another tree that had fruit of splendid flavor. The seed which he secured from these flowers was planted, and the seedlings which he grew were grafted the next year on another tree that bore early fruit.

The first crop after crossing the varieties was not so good as either of its parents. But when the second

crop arrived, it had gained one point. He then crossed it with another tree having the qualities he wished to produce; and working patiently year after year, he at last produced a cherry that may be marketed two weeks earlier than all others and that has all the other good points a cherry needs for shipping and eating.

One day Burbank heard of a seedless plum that grew in France.

"Why not have seedless fruit?" asked Burbank. "It costs time and money to take the stones from fruit. It costs the tree more energy to supply the stony covering for the seed than it does for all the rest of the fruit. Nature provided this stony covering to protect the seeds so they would not decay or be devoured before they had a chance to grow. But now we are growing our fruit trees from buds, not seeds; so why not do away with the seeds?"

Burbank sent for twigs of the seedless plum. It had a blue-black fruit which was soft and sour and about the size of a cranberry. Its small seed had a sort of stony covering, though it was not so hard as that of the usual plum. He decided that it had so little stone because it grew in soil that did not furnish the plant food to make one.

The next season Burbank fertilized some of the blossoms of these twigs with those of the French prune, and others with different kinds of excellent plums. He grafted the seedlings obtained from these crosses and grew a plum nearly twice the size of the

original, but it was still very sour and it still had a stone.

In time he gained some fruit that was almost stoneless. These he again grafted to good fruit. In six years he had a fruit with only the splinter of a seed stone. Working with these plums, he began to build up quality. It was very hard to protect this stoneless seed until he could plant it. Insects and fungus growth threatened to destroy it, but he packed it in dry sand and saved it.

The stoneless plum that Burbank perfected has a soft jelly-like substance instead of a seed. The plums are of several colors—white, pale yellow, orange, crimson, and blue, as well as mottled. They are large and sweet and delicious. The plumcot, another product of his skill, is a cross between the plum and the apricot.

The giant winter rhubarb, which is now being shipped from California, came in the first place from New Zealand. It was not so good in flavor as our rhubarb, but it was of winter-bearing stock. The first plants that were brought over were about the size of a lead pencil. These stalks produced many seeds, all of which were planted. From among the thousands of seedlings Burbank chose the best and crossed them with our home varieties. In New Zealand the plants bear in June, July, and August, which are the winter months there. Here in California, crossed with our summer-bearing specimens, they bear the year round.

The Shasta daisy was an attempt to get a pure white flower with a large blossom and a smooth stem and

leaf. Mr. Burbank began with the oxeye daisy, choosing the whitest blossoms he could find. He crossed them with the English oxeye, but still they were not white. Then he found that the Japanese daisy, though small and ragged, had perfectly white leaves. After working with the three for many patient years, he succeeded in producing the wonderful flowers with the snow-white petals which he has named for Mount Shasta. He has also grown a double daisy and a fringed daisy. They do not self-sow like the troublesome oxeye.

Giant dahlia zinnias

The original white blackberry grew wild in New Jersey. It was not pure white, but was almost colorless with a dull yellow tinge. He crossed this yellowish berry with the Lawton blackberry. The first year the stock was much like the Lawton berry. The next

A new rose

year he got a bush that fruited and bloomed all the year. It did not die down like the others, but grew as tall as a young tree. The fruit was small, soft, and black. There were very few bushes in the second planting that produced yellowish white berries.

Burbank noticed that the bushes that grew these were green or yellow instead of brown or purple like the others. He noted that the lighter stems produced the light-colored berries. Working with these bushes and crossing with berries of large size and good flavor,

he produced a pure white berry. Among several hundred bushes which were supposed to be just alike, there were four or five plants that produced white berries.

Burbank experimented many years to grow a thornless blackberry bush. He finally produced one that is free from thorns or brambles.

It occurred to him one day, as he was thinking how nature protects her plants, that all the plants of the desert are bitter, spiny, or poisonous. The sagebrush and cactus live and grow and scatter seed babies where other plants would die in a day. Though it may not rain for years, these plants, which are mostly water, reach down into the earth and keep themselves alive. Burbank thought if the cactus were protected as other plants are, that it would not need its spines and would stop producing them.

The cactus first grew near the inland seas in the desert. When these seas dried up, its roots grew longer. Its leaves grew narrower, and to prevent animals from devouring them, it grew the spines; or perhaps we would say that the species which had the spines survived. All other plants were destroyed except the bitter sage and the cactus with its prickles.

Burbank planted a thousand cactus seeds, and experimented until he had developed a new plant with broad leaves and velvety skin which proved a rich food for cattle. He worked on the cactus pear which he knew was used for food along the Mediterranean. This fruit grows on the edges of the leaves. The pears are three or four inches in length, and some

of them weigh half a pound. When the skin of the fruit is removed, the pulp is somewhat like a juicy watermelon, only more solid, sweeter, and of a more pronounced flavor. It may be eaten raw or cooked or preserved. Cactus candy made from this fruit is now very common. Fifty pears may grow on the edges of one broad leaf. The seeds are large and troublesome, but Burbank hopes to improve them.

Questions and Problems

1 How did Burbank produce a rhubarb plant that bears the year round?
2 How was the Shasta Daisy created?
3 Compare Burbank with some great inventor as to the good they have done to the world.
4 What qualities of mind does Mr. Burbank possess that enables him to succeed with plant life? Do you think anybody could carry on such work? Why or why not?
5 Which would you rather be: a Burbank, an Edison, or an Audubon? Give reasons.

CHAPTER XVIII

NIELS HANSEN, THE PLANT EXPLORER

ANOTHER man who has done much for plant development in colder regions is Niels Hansen. The Hansen family came from Denmark to America in 1873, and a few years later settled in Des Moines, Iowa. When Niels was seventeen years of age, he entered the Iowa State College at Ames and was graduated from there.

Being much interested in plants and how to improve them, Niels spent four years in a plant nursery where he learned how to take the pollen from one kind of plant and put it on the pistil of another, and thus grow a new variety different from either parent. He did this with fruits and brought forth better fruits. All this creating of new varieties was tremendously interesting.

In 1895 he was called to Brookings, South Dakota, to be the head of the State Experiment Station. Here was a plant-breeding greenhouse. In it Hansen set to work to improve the fruits of the Northwest. It was too cold there for many fruits to live. So Hansen kept watching for the hardiest plants and fruits and selected these to cross-fertilize with one another, until he produced strong plants that would stand the below-zero cold of this region and the long dry season of the desert.

By hand he carried delicate pollen dust from one blossom to another, and with a knife or a camel's-

hair brush inserted it just where it would mingle with the seed food of the other plant and grow into something new and different. He worked on eight thousand blossoms, and from these he chose two hundred and twenty-five for further experiment. The work required much intelligence, skill, patience, and hard labor.

Hansen produced a luscious strawberry by crossing the wild plant with the common garden variety. He crossed the raspberry of North Dakota with the Shaffer berry of New York and made a hardy new fruit. He crossed the native Indian plum with the California plum. These new fruit trees will stand a temperature of forty degrees below zero without any covering whatever. In creating new fruits, Hansen is second only to Burbank in what he has done for mankind.

But his best gift to the world was in finding new varieties of alfalfa for the farmers of the Northwest. Alfalfa is a nourishing plant food for cattle, and a very profitable crop. It gathers nitrogen from the air and, like clover, leaves some of it to enrich the soil. For these reasons farmers everywhere rejoice when they can find a variety of alfalfa that is suitable to their soil and climate.

Many thousand years ago alfalfa was the chief crop between India and the Mediterranean Sea. From there it was later carried into Persia and from there to Greece, Italy, and Spain. Centuries later it was carried by Spaniards into South America and from there to California. When this alfalfa was tried in the cold Northwest, it would not flourish. It was killed

either by extreme frost or by the dry weather of summer.

Hansen believed that a hardier variety of alfalfa could be found in the early home of the plant somewhere in Asia. So firm was his faith that when our government asked him in 1897 to go to Asia to search for new plants, he readily consented.

The journey was full of adventure. Hansen went first to Russia to gain what information he could. Then he crossed into Asia, traveling thousands of miles, until at last he found in China what he was searching for—a hardy alfalfa plant. Still he was not satisfied, for he wished to find the hardiest of all alfalfas. Hearing that it was to be found in Turkestan, he hurried northward across deserts and wild mountain ranges. Hansen traveled by caravan for over a thousand miles to latitude forty-five degrees north.

Here he and his company gathered the seed out on the cold steppes of Asia. Winter soon broke upon him with a violent blizzard. At the risk of his life Hansen pushed on to Omsk on the Trans-Siberian Railroad, a trip of seven hundred miles. His Tartar drivers lost their way, and he had to spend the night out of doors in a piercing storm. Two men in another caravan froze to death, but Hansen was saved by his reindeer suit which covered him from the top of his head to his fur boots.

However, he was taken ill and compelled to stay in a military hospital at which they arrived the next day. He recovered, and after another terrible drive of

Niels Hansen

three days reached the railroad which carried him to safety. Thus he came home with new cold-resisting alfalfa seeds for the American farmers.

In 1906 he made a second trip for our government to Siberia, where he discovered a still hardier variety of alfalfa with a yellow flower. He gathered some seeds of this on the steppes near the Obi River in Central Siberia. Then he went nearly two thousand miles farther east and got other seeds in Manchuria. He also visited Lapland on this trip. He had to take with him three interpreters—one to translate Chinese into Tartar, another to turn Tartar into Russian, and a third to change Russian into German, which he himself could speak.

Such good results came from Hansen's plant explorations that our government asked him to make a third trip. This time he went to both Mongolia and to North Africa. In the former place he found the spot farthest north where the yellow-flowered alfalfa would grow. This was sixty-eight degrees north latitude and is said to be about the coldest spot on earth. During his journey he was in constant danger from bandits and came perilously near to places that were suffering from the dreaded cholera, but fortunately he reached home safely with more seeds.

Now came the task of planting the alfalfa seeds and raising enough to supply the eager farmers. From one spoonful of seed there was produced from repeated plantings one thousand bushels. One alfalfa plant produced in one year 41,430 seeds.

This new yellow-flowered alfalfa has proved to be

just the kind to stand the climate in the cold and dry regions of our country, and it means millions of dollars for our farmers in a few years.

Hansen went to Asia again for more seed, sent this time by the state of South Dakota. On the borders of Persia he found a large, delicious grape of which he obtained five hundred vines. In the Altai Mountains he discovered seeds and plants of a wild currant larger than the cherry currant which we have. He found also a wild hardy blackberry and a Persian clover which is one of the finest plants for cattle, and which, like alfalfa, needs replanting only once in five or six years.

Hansen has received many honors for his splendid service to America. He might have made a fortune out of his discoveries, but he has given his service freely to his people. He thinks, and rightly, that he is doing the Lord's work by helping to make life easier for all men.

Questions and Problems

1 How did Hansen get fruit that would thrive in the cold dry states?
2 Why is alfalfa a valuable crop for the farmer?
3 How did Hansen get an alfalfa plant that fitted the colder climate of our Northwest?
4 Name all the plants you can that have come to America in recent years.
5 Do you think all plants can be further improved?

CHAPTER XIX

HOW WE CONSERVE THE SOIL

NATURE has given to the people of America a wonderful land. We have broad fertile prairies, great grazing regions of juicy bluegrass, and hills and mountains covered with valuable forests. Underneath the soil are concealed rich deposits of coal, oil, iron, copper, and other minerals. Rivers and lakes furnish cheap transportation and water for city use and for irrigation. These riches, together with a livable climate and abundant rainfall in most sections, make our land a fit home for a great nation.

These rich provisions of nature for man's use, however, will not last throughout all time unless they are cared for and used intelligently. In other words, we must conserve what nature has provided for us. Conservation does not mean that we shall lock up our riches as a miser does his gold. It rather means wise, careful use of our natural resources.

Since the land has much to do with the food of man, we should begin with conserving the soil. If a farmer or gardener abuses the soil on his land in such a way that it becomes poorer and poorer, he is only cheating himself in the long run. The farmer who puts back into the soil the elements that make it fertile not only makes it produce more for himself and his children, but he will get more for the land if he is obliged to sell it.

Canaan, the land of promise, was once a rich region "flowing with milk and honey," as we read in the

Bible. It had grapes, vast forests of cedar, fir, and oak, great wheat crops, and many fine olive groves. Now nearly all are gone. The traveler in the Holy Land finds a most desolate region with the few inhabitants working very hard to make a scanty living.

In the days of Rome's greatness Sicily was called the granary of the Roman Republic, because from this small island came the grain to feed vast armies. Twelve million bushels of wheat a year were shipped from Sicily to Rome, and yet Sicily had enough left for her own people. To-day the entire island does not raise a million and a half bushels of wheat altogether. The soil is barren and the citizens are scattered. They allowed the soil to be worn out until it would no longer furnish enough food for its own people.

In our own country we are wearing out the soil altogether too rapidly. There are many things that are wasting away the soil. The first is running water. A farmer, let us say, owns a good farm on the side of a hill. Much of it is good wheat land, but the highest ground is covered with forests. The farmer decides to cut down the timber and use the land for raising more wheat. He does so, but then there are no trees to stop the heavy rains as they fall to the ground. As the drops sink below the surface there are no tangling roots to hold the water for a time in the soil. So it runs rapidly down the hillside, carrying with it some of the topmost and richest earth. Each year the crops on these fields become a little poorer until finally it hardly pays to plant or sow.

This process goes on continually in deforested hilly

states like Kentucky, where, it is said, one tenth of the land area has lost its best soil altogether and a considerable part of the state could not be restored to its former fertility in a lifetime.

The chief remedy for this loss in the soil is to preserve our forest regions, especially on the sides of hills and mountains. But there are others that will help somewhat. One of these is what is called "contour plowing." This means that the farmer so plans the plowing of his fields that the furrows of the plow will go around the hill on a level. The water coming down the hill is caught in these furrows and is absorbed instead of rushing on down the slope. It is saved to make the land moist and to nourish the crops instead of running down the hill, carrying away with it the rich soil.

Another way to keep the soil from washing away is by building terraces around the hill. This makes a part of the slope much less steep, but it also makes the part between the terraces much steeper than before. On these slopes of the terraces grass should be planted, so that the roots may protect and hold the earth from washing away. A terraced farm is not adapted to ordinary farming, but it may well be planted with fruit trees. Planting belts of apple, pear, peach, or cherry trees will serve the same purpose as planting a forest again, for the slopes are once more covered with trees. Bands of forest trees should have been left around all hills to protect the soil from washing away.

Where many gullies that stretch into the plowed

land have been formed, it is the custom of the best farmers to plant grass, shrubbery, or even trees, so that the gullies may not be allowed to wear deeper; for the deeper they are, the swifter and deeper is the water that rushes through them and the faster the rich soil is carried away.

Treeless region in Idaho

But water often washes away land that is not on slopes. We are told that the Mississippi River carries to the sea so much soil each year that if one hundred thousand men should stand on its banks with shovels, they could not, in a whole year, shovel into the stream as much loose earth as the river now carries down to the gulf.

An observer says:

"Drifting down the Mississippi, I have been aroused in my boat by a roar like continual thunder, to discover a mile or two away a forested bank caving into the river, the rich earth falling away, the mighty trees, a century old, crashing over one after the other into the stream. I have seen a mass of land, an acre in extent and standing forty feet above the level of the water, fine black soil all through, able to produce more than a bale of cotton to the acre, suddenly, and without warning, crack loose and sink swiftly and noiselessly beneath the surface of the Mississippi. Such slips occur not occasionally but daily in a thousand places along the river."

The storms, however, do the most damage. Some one has said it this way: "The greatest storm of a summer will doubtless carry away more soil than all the other storms of that summer. The greatest storm of a year may do more damage than all the other storms of that year. The greatest storm of ten years may well do more damage than all the other storms of that decade." Anything we may do to check these floods with their vast flow of water will tend to keep the rich surface from being washed away and lost. Planting new forests near the sources of rivers and building large reservoirs for water storage would check this loss of soil.

If we look at the plants that grow to furnish us food, we shall find eight elements which make up the plant. They are hydrogen, oxygen, carbon, silicon, calcium, nitrogen, potassium, and phosphorus. We have in water all the hydrogen and oxygen we need. We have

all the necessary carbon in the carbon-dioxide gas of the air. We can get silicon from sand, and calcium from lime or limestone. If the soil wears out, it is generally because the other three elements—nitrogen, potassium, and phosphorus—are not so plentiful as they once were. To conserve the soil, then, it is necessary to save or restore these three elements.

Let us study these elements one at a time and see what plans we may make for conserving the soil by checking the waste of each. Nitrogen is a very important element in the food of man. It exists in large quantities in the air, but plants cannot take nitrogen from the air without some assistance. However, there is a great deal of nitrogen in the soil in the form of nitrates. It is in what we call the humus. Whenever this nitrogen of the humus is taken up by plants, it is necessary that it be put back again.

The most practical way of replacing nitrogen is to grow clover, peas, or beans. These plants have on their roots little projections which are full of bacteria. The bacteria have the power of taking nitrogen from the air and storing it in the plant. When this plant is plowed under the soil, the nitrogen once more enters the humus and makes it as rich in nitrogen as ever. That is the reason that the wise farmer sometimes plows under his crop of clover, apparently wasting his hay, but enriching his land again.

The farmer also scatters the manure from the barnyard over his land, because it, too, is rich in nitrogen. Nitrogen in the form of nitrates to be used as fertilizer for farm lands is also shipped to this country

from Chile at great expense. In every thunderstorm vast quantities of nitrogen from the air are turned into nitrates, some of which come down with the rain and sink into the earth.

In Norway and some other European countries where water power is cheap and abundant, this power is changed into electricity and used to collect nitrogen from the air to be used to enrich the poor soil of Norway. This we are beginning to do at Muscle Shoals, Alabama. Thus we see that the problem of supplying nitrogen to the fields is difficult and expensive, but it can be solved if we pay the price.

The next element to be saved is potassium, of which the crust of the earth contains about two and a half per cent. Besides this there are large supplies of rich potassium deposits in Europe, which are said to be enough to last all the world for thousands of years. During the World War this supply was cut off, and our crops suffered. Perhaps we shall find a way to get it from certain rocks which contain portions of it.

The last of the elements to be conserved is phosphorus. It is necessary for blood and flesh and bone and brain. In a station in Wisconsin an experiment was tried upon animals. They were fed with food in which there was very little phosphorus. The result was that while they seemed to thrive for a time, they became gradually weaker, and after three months they collapsed.

Just before this breakdown a few of them were killed, and it was found that the flesh was taking the phosphorus from the bones to supply its needs. This

process had gone on until the bones had so little phosphorus that the collapse came. The people in charge then tried to make some of the animals strong and healthy again by giving them food containing phosphorus, but it was too late.

It may be of interest to know that the greater part of the phosphorus in wheat is in the bran; in fact, almost all of it. This should teach us that it is wiser to eat whole-wheat bread instead of white bread.

Phosphorus is needed in the body. It is also necessary for growing crops. Just as there are some places in this country where the size of the crop depends upon the amount of rainfall in a season, so there are other places where it depends upon the amount of phosphorus in the soil. The production of the same crops year after year has reduced the supply of phosphorus in the fields. Tests made in Wisconsin show that on the average farm that has been plowed for fifty years, the soil has already lost one third of its original phosphorus. Experiments in Illinois, Wisconsin, and Ohio have proven that an increase of nine bushels of corn to the acre came as a result of adding raw phosphate during the five preceding years.

How may we save this phosphorus, or, at least, a great part of it? First of all, we should use all the manure which we have to enrich our farms. It is in many cases the remains of straw, hay, grain, and other refuse produced on the farms. A great deal of phosphorus goes into the refuse of every city, and becomes a part of the sewage that is now allowed to pollute the

streams that flow by the cities. A system has been devised by which this sewage may be treated, the water purified, and the valuable fertilizing products saved. These spread upon the farms make up not only the loss of phosphorus but of nitrogen as well.

The first phosphate to be used as a fertilizer was guano. This is procured from islands off the western coast of South America. The phosphorus is first taken up by plant life in the ocean. Fishes live on these plants. The birds in turn feed upon these fishes, and drop the guano on the rocks of these barren islands, where it is gathered and shipped away as fertilizer for the soil.

It is interesting to notice that the birds producing the guano were protected in olden times by the laws of the Incas in Peru, which made it a crime punishable by death to kill the sea fowl, to gather their eggs, or even to visit the islands in the breeding season. In our civilization no laws protect the birds. The robbery of the eggs on a large scale and the killing of the birds both old and young have been going on for years.

Phosphorus is also found in phosphate rock, many beds of which are found in the United States. Unfortunately, however, much of this phosphate rock is mined and shipped to France, England, and other European countries, in spite of the fact that we need it very much in our own country.

Although, as we have seen, nitrogen, potassium, and phosphorus are the chief needs of our soil, it sometimes happens that the soil has all these in

abundance and yet will not produce grain in any amount. Generally, in these cases, it will be found that there is too much acid in the soil. It is an easy matter to test this by getting blue litmus paper and putting it in a little wet earth from the field. If the paper turns decidedly red, there is too much acid in the soil; and the remedy is to scatter over it a bountiful supply of powdered limestone, which will counteract the acid and make the land sweet and fertile again.

Sand plains of Columbia River—Spot reclaimed by poplars

It was formerly noticed in England that in some places the crops were much better along the dusty roads than they were a little distance away. As the soil was as rich in one place as the other and had been treated all over with fertilizers equally, people began to inquire the reason for the difference in the

crop. It happened that most of the roads in that section of England were made of limestone, and it was soon discovered that the powdered limestone dust had made the change. When the powdered limestone was scattered over the soil of the other lands, the crop back in the field proved equally good. The elements needed by plants were there all the time, but the oversupply of acid in the soil had to be overcome by the lime before the soil could produce.

Questions and Problems

1 Why has Sicily a barren soil to-day? How might it have been prevented?
2 How may running water injure the soil?
3 How may this be prevented?
4 What are the three chief elements of soil that farmers must look out for?
5 Report on nitrogen for fertilizers. (See nitrates from Chile.)
6 Find out all you can about phosphorus.
7 From books on agriculture you may learn more about fertilizers.
8 Read how limestone makes the famous Blue Grass Region of Kentucky.

CHAPTER XX

PRESERVING OUR FORESTS

THERE are many beautiful trees in the world, and many are the uses of wood and timber. The pines and conifers have narrow leaves or needles. They are soft wood trees and usually grow on the mountains or in the cooler regions. Some of these trees are very large. Giant pines grow over a hundred feet tall. In California in the range of the sea fogs, some of the marvelous redwoods reach the height of two hundred fifty feet. Douglas firs and spruces sometimes grow to one hundred eighty feet.

The broad-leaved or deciduous trees shed their leaves and provide the hard woods used in cabinet work. The grain of the slow-growing white oak is very fine. Maple has a waved and mottled grain. The wood of the hickory is elastic and is used in vehicle building. Trees of this kind are very slow of growth. There are historic elms in New England known to be hundreds of years old.

The beech, walnut, oak, and hickory all bear nuts, while the mountain ash, the pepper tree, the wild cherry, the wild plum, and the persimmon furnish fruit and berries for the birds and small wild creatures. In the days of our forefathers, all clothing colored brown was dipped in the brown dye of the butternut tree.

In that early day houses were built of logs and later

of rails, and for many years in the United States most of the houses were built of wood. In many tropical countries, like Japan, where earthquakes are frequent, the light bamboo is used.

There are many products from the wild trees as well as from those we have cultivated, for all our wonderful fruit trees and orchards came at one time from the forest. South America has a cow tree that has a white thick sap like cream. Rubber is made from a tropical tree whose gum supplies our automobile tires. Our maple tree with the foliage that turns to brilliant colors in the fall supplies a sap that is boiled into sugar. The southern pine furnishes turpentine and resin.

In the warmer zones are varieties of palms, including the date and the coconut palm and the eucalyptus trees, that lose their bark instead of their leaves. There are also many flowering trees, like the magnolia and acacia, while farther north are the redbuds, dogwoods, buckeyes, and the wild crab trees.

In the jungles of South America and Africa the trees crowd so close that they have few branches but reach upward toward the light. They are loaded with moss and vines. Here magnificent hardwoods, like mahogany, ebony, rosewood, and sandalwood, decay far from transportation and the service of man.

The date palm which is now being grown on the deserts of the United States comes from Africa.

Only the Eskimo and the men of the very cold regions have learned to live without wood. Civilized man has always had growing close at hand plenty of

Giant California redwoods

timber for fuel and for shelter. Our forefathers came to the wonderful forests of the United States and chopped and burned acre after acre of woodland with only the thought of clearing the ground. William Penn tried to get his people to spare one acre of trees in every five they cleared. But it was not till 1876 that people awoke to the fact that some day our trees would all be gone, and an agency was established in the United States to study our forest conditions.

In 1891 Congress authorized the President to set aside forest preserves in order to protect the remaining timber from destruction. The Yellowstone Park Timberland Reserve was created by President Harrison. Now about two thirds of all the timberland of the west is in national forests. They are open to all for pleasure and recreation, but no one is allowed to cut the timber except by special permission. Ripe timber is sold for a reasonable price to the highest bidder, and room is made for a second crop. In this way some of our valuable timber will be spared for future generations.

Saving the lumber of the forests for future generations is not the only reason for saving the forests. As we have seen in the chapter on soil, forests have a great influence on erosion. Where the slopes are steep, almost the only way to prevent the soil being washed down into the valleys is to keep the slope well wooded.

Forests also have an influence on the climate of a region. Much of the rain that falls beneath the trees dissolves plant food from the soil. This is taken up

by the roots of plants and trees and carried upward to the leaves. The trees and plants absorb all the food and much of the water, but the rest of the water is breathed out through the leaves into the air. This gives to the air over the forests a coolness which is felt by balloonists and aviators three thousand feet above the earth. Thus we see that forests in a region often make the climate cooler.

Norway pine—a newly-planted forest in Michigan

Forests are also known to increase the rainfall of a country. Rain is caused by the cooling of the vapor in the air. The cool air over the forest chills the passing moisture and causes it to fall as rain. Experiments carried on for thirty-three years in a forest of eighteen thousand acres in France show that for every thirty-six inches of rainfall in the center of

the forest there were only thirty inches at the edge of the woods and twenty-four inches in the open field ten miles away.

Years ago Kansas was a prairie state with few trees and no crops. Dry plains stretched halfway across the state. Thousands of acres of trees have been planted, and now great crops of grain are raised. The more trees and crops the farmer plants the more rain comes to water them. The great droughts that used to make the country a burned plain now seldom come. Kansas is one of the most productive states in the Union, and its productivity is due in part to the planting of trees.

Forests on steep slopes help to prevent floods. Beneath the trees of the forest is a thick covering of leaves and twigs which rests upon a very porous mold that takes up water like a sponge. This water is held and allowed to escape very slowly. It then passes along under ground and reaches the streams very gradually through seepage and springs.

The experience of foreign countries also proves that forests prevent floods. In Italy the Appenines have been stripped of their forests; the result has been marked floods of the Po River. This has led the Italian government to reforest nearly a million acres. In Austria the forests have been cut from many of the mountains with the result that great floods have occurred on the Tyrol. To prevent these floods, the government began before the war to replace the forests along a hundred streams.

In our own country where the hills and valleys have

been deforested, serious floods occur, while other regions that are forest-covered give off a more even flow. For example, the north fork of the Yuba River of California is forest-covered, while the south fork has had its forests cut. The former has a river basin of 139 square miles and the latter one of 120 square miles. The first never has less than 113 cubic feet of water a second running through it, while the second for four months of the year has practically no water.

The replanting of forests is now going on in almost every country in the world. In France, not only the headwaters of the Rhone and Seine have been replanted since the forests were cut down, but the sand dunes have been treated in the same way. In some European countries it is against the law to cut a tree unless another is immediately planted to take its place. The Forest Service of the United States is planting from twelve thousand to fifteen thousand acres of trees yearly.

In Wisconsin a rather interesting experiment is being tried. The state is rich. Her furniture factories, her paper mills, and her boat works are known throughout the world. But twenty years ago she found her forests almost gone, her rivers running wild in the flood season, and her navigation lost because of low water in the summer.

It was about this time that a young man came from the forest schools of Europe to be a forester of the state. Upon the central highland of Wisconsin, where all the streams rise, he undertook to plant trees in a reserve of three million acres. All over the state were

small tracts of pine forests belonging to the state. These tracts he sold off as farms, but carefully saved the trees and replanted the central highland as fast as he could. It was not long before the mill owners

White pine plantation

on the Wisconsin River noticed a more even flow of water for power. They took steps to still further increase the water flow, and he was the adviser to whom they applied for aid.

The United States at one time had forests which

for extent and value were not equaled by those of any other nation. Yet of the original millions of acres of timberland scarcely one half is still covered with forests, and much of that has been cut over so many times that less than one third of the best timber is now standing. The time has come when lumber is so scarce that other materials, such as brick, tile, and stucco, are being used for houses.

Let us see how the wood that is cut every year is used. First of all there is the firewood, but as this is largely cut from dead timber from the wood lots, or the waste from the lumber region, the hundred million cords cut every year does not make so great a drain on the forests as one might think.

It is said that twenty times as much timber is sawed into lumber as is used in any other way. Most of this lumber is used for building wooden houses, barns, and sheds, while still more is used for doors, windows, and inside furnishings of brick and stone houses. Then much selected lumber is used for furniture, wagons, plows, harvesters, and other tools. We use lumber for the making of cars, railroad ties, barrels, mine timbers, boxes, crates, clothespins, spools, matches, and even toothpicks. Some of it is ground into pulp to be used in making paper for our books. Some of the more expensive woods are used for veneer. Thin sheets are cut into small strips and glued to cheaper woods as a finish for furniture. The bark of some trees is used in tanning leather.

Turpentine and rosin are produced from the sap of certain growing trees. Tapping trees need not de-

stroy the growing forests any more than tapping maple trees destroys them, but the method formerly in use was destructive. The trees were "boxed"; that is, cuts five or six inches deep and several inches long were made in the trees, so that oftentimes in the southern forests you may see hundreds of trees hacked three fourths of the way around as high as the ax could reach. This method takes away the strength of the trees, so that they soon die and fall. The United States Forest Service has devised new methods of getting the sap with the result that the trees last five times as long and yield a third more sap each year.

The greatest waste is in the forest itself. One writer says he would not be surprised to learn that of all the wood that is cut fully two thirds is wasted in the forests. It is left to decay or it is burned. One reason for this waste is that the great forests left in the United States are so far from the building centers, and the cost of freight is so high that it pays to ship only the best grades of lumber to market. This means that all the upper parts of the trunk and the branches of the trees are cast aside and burned, because the lumber made from these would be full of knots. In one mill in Alabama a pile of branches and waste wood as high as a two-story house burns night and day throughout the year. The same is true of other large mills.

There is also much waste in lumber manufacturing. Some of this waste is due to the use of very thick saws which cut away too much wood in sawdust. Then it is the habit of the lumber trade to limit the length of the

sizes of lumber sold. The custom now is to sell nothing under ten feet, and very little under twelve. This means that in sawing a log, every cut shorter than ten feet is thrown away. These shorter lengths could often be used, and they could be sold at a lower rate than the standard lengths. The pieces which are

Wasteful lumbering

too small for short boards could be used for matches, toothpicks, excelsior, or even for toys. As it is, some of the largest and best trees are now being used for matches.

We are told that out of every eight thousand feet of timber that is cut down two thousand feet are lost in the forest and never reach the sawmill at all. Two thousand feet more are lost in sawdust, short lengths,

and the like at the mill, leaving only four thousand feet to be sent to the factory as lumber. In the factory one thousand feet more are lost, so that less than half is left to be used in the making of furniture. This great waste is unnecessary.

Burned-over area

Fire, it is said, has ruined more timber than has been cut by man in the United States since the discovery of Amerca. It is reported that fifty million acres of woodland are burned over every year. This doubtless includes lands in which the standing timber is not destroyed, but the small saplings are killed, and thus the hope of future growth is gone; but it also includes fifteen million acres where the standing timber

is totally ruined. This means forty thousand acres every day in the year.

The work of the Forest Service in fighting fires has reduced the loss to thirty thousand acres a day. Forests that would make our country a better place to live in and our people more comfortable and happy are allowed to burn at the rate of thirty thousand acres

Scene of devastation

a day. If one could gather in one vast heap our houses and barns, our furniture, our wagons, our railroad ties, our telephone poles, our papers and magazines, and burn them all, the loss would astonish the whole world. But we sit idly by and see the materials of which all these things must be made in the future, and with them our shade and the very soil of the

lands, destroyed, with scarcely a word of protest.

What are the causes of forest fires? In the first place the débris that will burn in the woods includes dry leaves, twigs, fallen timber, dead trees, and slashings made by timber cutting. All this débris is soon dry and ready to burn. It needs only a spark, and the forest is ablaze. An investigation of some 2503 fires in the Rocky Mountain district in 1907 showed 641 fires caused by locomotives, 638 by campers, 458 by lightning, 49 by brush burning, 43 set by criminals, 22 by hunters, and 652 unknown.

How can these fires be prevented or at least controlled? In one country in Europe the average area burned over yearly is less than one fiftieth of one per cent. How can we make such a record in this country?

Forest rangers now make a regular patrol of the forests during the fire season. The area is guarded by lookouts. The moment a fire is seen and exactly located, men are called by telephone. The ranger knows just how he can secure men and equipment. Such a patrol enforces the fire laws among those who travel in the forest; and when, in spite of this, an occasional fire occurs, all the patrol men from the surrounding forest gather at the sight of the smoke to put out the fire. Such a patrol has been found to cost not more than two or three cents an acre. In some dry regions captive balloons remain in the air with a lookout watching for smoke or signs of fire to give the warning.

Should a fire get a start, it is essential that there be

belts on which a fire fight may be made. In the great Chicago fire of 1871, the government took control and blew up a block of buildings to make a gap which the fire could not easily cross. A fire lane is a wide path in the woods from which everything is cleared for a width of from twenty-five to one hundred feet, according to the conditions of the forest. All the great forests that belong to the province of Ontario are patrolled regularly and thoroughly in the summer months. As a result, forest fires are few.

Forest fires will be fewer when all slashings are burned as the timber is taken out; when all railroad engines are equipped with spark arresters; when brush is burned in the rainy season; and when travelers are more careful with camp fires.

The work of our Forest Service is under the forester and his assistant. Every national forest is divided into ranger districts of about two hundred thousand acres. The district ranger supervises the sales of timber, lets out acres to grazers, and helps to build roads, trails, bridges, and telephone lines.

Questions and Problems

1 Name some hard woods and tell of their uses. Where do they grow?
2 From what trees do men use the sap? Where do these trees grow?
3 Would it be easier for mankind to live without wood or without iron? Give reasons.
4 Locate the various Forest Preserves in the United States.
5 How do forests influence climate?
6 Write the Forest Service, Department of Agriculture, Washington, D.C., for pamphlets on reforestation.

CHAPTER XXI

IMPORTANCE OF WATER STORAGE

HAVE you ever seen Niagara Falls? Have you ever stood at the foot of Goat Island with the great white sheet of the American Falls plunging before you down that precipice of nearly one hundred seventy feet? If you have not, you have missed seeing one of the grandest sights in the world. There are other cataracts that fall from a greater height. There are others that sometimes have a greater volume, but the steady, magnificent flow of such an enormous amount of water is a sight that you may well go thousands of miles to see. "There is but one Niagara."

Whence comes the steady flow? Why are there no others that match it? The answer is not far to seek. Niagara's source is in a vast reservoir—the five Great Lakes which pour forth an even stream. The headwaters are dammed by nature so that the flow is made steady. The Great Lakes occupy over sixty-six thousand square miles, which is more than one sixth of the entire basin drained by the river. If other rivers had their headwaters stored as the St. Lawrence has, their flow would also be constant and dependable, and we should not need to be concerned about our water supply.

In considering the conservation of water, we at once come to a marked difference between the conservation of water and that of lumber, for example. Some lumber is used for fuel, some for furniture, some for build-

ings. In the same way, water is used for navigation, for water power, for irrigation, and for the water supply of cities; but the lumber for fuel cannot be used for anything else, whereas water may be stored, used over and over again as water power, used again for navigation, and once more perhaps for the supply of cities.

Mississippi River Dam taken over by Henry Ford

Nothing in the world is more destructive than a great flood. A river receiving too much water at one time swells until it overflows its banks. It fills the streets of the cities, flows into houses and factories, puts out furnace fires, stops business, and causes losses of millions of dollars in a single city. In the country

it sweeps over the fields, carries away the crops that are waiting to be harvested, and deposits sand, timbers, and refuse over the farms in the valley.

The Ohio River at Cincinnati sometimes rises sixty-five feet above normal low-water mark, so that in flood time a shallow steamer might safely float over a six-story warehouse built on the banks of the river. A single flood in the Missouri Valley in 1903 is said to have done not less than twenty-five million dollars' worth of damage. The Ohio River probably does as much damage every year in its own valley. A flood in the Seine in France in 1910 is said to have cost that nation two hundred million dollars.

Floods are water wasted—indeed, worse than wasted. They are a menace to the surrounding property, against which we must build great levees. Levees have been, thus far, only fairly successful. The Mississippi River, from Cairo to the sea, flows along a bed which winds through a valley between bluffs forty miles apart. When the floods come, they fill this entire valley. A torrent in places forty miles wide sweeps over cities and through woods and fields to the Gulf of Mexico. There are now along the banks of the Mississippi fourteen hundred miles of levee, which save thirty thousand square miles of land, as rich as any in America, from being overflowed. The levees cost a trifle more than sixty million dollars. Year after year the river rises in its might against them. Year after year the giant bites at them, trying to find a crawfish hole through which to make an opening. And then just when we feel certain that we have the

flood monster curbed, he finds a weak spot, the soft earth sloughs away, there is a roar of water, and thousands of men rush to the rescue with every means known for keeping back floods. Perhaps they find themselves powerless to stop the torrent.

Ashokan Dam supplying water for New York City

How much better it would be to prevent the flood from forming. The people of Louisiana cannot do it, although the nation helped them to pay for the levees they now have. Floods cannot be prevented in Louisiana at all. It must be done in Montana, in Minnesota, in Pennsylvania, and in West Virginia. How? By water storage.

Before explaining what is meant by water storage,

let us consider one or two facts. The Connecticut River rises in northern New Hampshire, receives many tributaries, and flows into Long Island Sound. Each of the tributaries is lined with mills that depend upon the streams for water power. The river itself at Holyoke and other places furnishes great water power. The lower part of the river, from Hartford to the sound, is a navigable stream with a ten-foot channel.

The people of Hartford want to make it eighteen feet deep. The summer of 1908 was very dry, and the river became very low. There was not water enough to use in the paper mills of Holyoke, and none at all for power. The mills had to close. In the fall the rain came, and this rain and melted snow caused a flood that made the factories shut down again. The river rose, until at Hartford it was twenty-six feet deeper than at low water, and it did much damage.

But worst of all was the waste of water. If the flood that went to waste in one day had been saved and used in the dry time, it would have kept an eighteen-foot channel filled for one month. And if what went to waste in a week had been saved for the dry season, it would have been enough to keep the channel open all through the dry season of summer and fall. More than that, it would have kept the Holyoke mills running through high water and low water.

So the storing of water is the best method of preventing floods—to confine it at headwaters in great reservoirs and save it until it is needed. In this manner we may establish a water-storage system, or dam,

store the water in it, and draw upon it when necessary as we draw money from a savings bank. It will pay abundant interest while it is stored, for the overflow will keep the river going in the wet season, and the surplus in the reservoir can be drawn upon when it is needed in the dry season.

"White Coal" Dam on the Missouri River at Great Falls

As an example of what is possible, let us look at what has been done in Europe. A certain stream there flows through three countries and supplies water power for many villages. In July, 1897, it suddenly swelled to a torrent, overran its banks, and deluged the valley, ruining mills and homes. What was to be done? The damage had come, and if the same conditions remained, it was sure to come again.

The mayor of a little village, therefore, called a meeting of the representatives of three states. Four hundred men met and faced the question. They came to look upon water in two ways—first as a destroying force that must be curbed, and second as a public servant, able to do a great, helpful work if it did not break away from them. The people taxed themselves for a million dollars, and with this they built six dams in the headwaters of the branches of the main river. The lakes thus formed were stocked with fish and furnished a food supply. The lakes also made the mountain scenery more attractive and brought tourists and sportsmen to spend their money in the neighborhood. The millers now have a steady flow in the stream all the year, and the mills never shut down for lack of power. The floods have ceased and there can be no more. This was the result of water storage. The same thing is being done yearly in our own country in the arid regions of the southwest.

Water storage is the basis of all reforms in conservation. Every acre we water calls for storage. Every waterfall which we change to electricity must have a storage lake above it which will carry it through drought, and be a safety valve in flood times. Every river on which we wish boats to run throughout the year must have at all times the water necessary to float the boats.

Water at the right time is of great value to the public. Water at the wrong time is a menace. The moral is easy to see. We must hold back the flood and use it when it is needed. This requires a reservoir and a

dam. The dam-site must, if possible, be so selected that it may have a rock foundation and as narrow a mouth as can be found. It should be built of hardpan, concrete, or stone. It should have a spillway to carry off water when the reservoir is full. It must have gates through which all the water may be drawn out as needed. If the dam is in a navigable stream, it must have locks through which boats may pass from one

Wilson Dam at Muscle Shoals on the Tennessee River

level to the other. Power plants may often be built at the outlet, but these are not so reliable, we are told, as those lower down the stream. Such reservoirs are built in the mountains of California to store and furnish water for the dry regions.

Under the direction of the government, reservoirs have been erected along the headwaters of the Mississippi to reduce floods and aid navigation. This river rises, as you know, in small lakes in northern Minnesota. It flows down in a series of rapids that end

in St. Anthony's Falls at Minneapolis. Below these falls, the river is navigable except in very dry summers. Before the reservoirs were built the river in late summer at St. Paul was often less than one foot deep. The power at St. Anthony's Falls was shut off in time of floods, and was of very little use in late summer.

Gatun locks on the Panama Canal

The reservoirs are able now to store nearly one hundred million cubic feet of water which, by lowering the bear-trap dam, may be used as needed. It is the largest artificial water storage in America, the greatest water savings bank in the world. The result has

been to keep the Mississippi at St. Paul never less than three feet deep, and to control the floods. The reservoir has made the water power at the falls steady. Experts estimate that it has added five hundred thousand dollars annually to the value of the water power of Minneapolis alone.

When the state forester of Wisconsin established his forest reserves among the headwaters of the Wisconsin streams, the mill owners at Stevens Point and Grand Rapids and other towns along the Wisconsin River noticed the effect of the forests on the steadiness of the current. Since the constitution of the state forbade the state from undertaking such public works, he secured from the state legislature a law allowing the mill owners to organize a corporation not for profit. It is called the Wisconsin Valley Improvement Association, and has a paid-up capital of one hundred thousand dollars. This association, under the control of the forester, has the right to condemn land suitable for water storage and to use ponds in the state forest preserve.

The forester sets up two monuments. The water is not to be raised above the one, nor drawn out below the other. This insures the beauty of the region which is now a great state park. The corporation builds the dam and hires men to work the sluice gates.

By 1910 they had opened up four billion feet of storage, and had surveyed enough for twenty billions more. Every water power plant on the river has doubled in value. Instead of shutting down or using coal in the dry season as other mill owners must,

those on the Wisconsin go ahead on stored water. The lower river, which has been so long unnavigable, now has a steady current, and will no doubt be used again.

So great has been the success of his water savings bank that the forester has been called upon by the mill owners of the other big rivers of the state to work out the same system for them.

Questions and Problems

1 Why is there such a steady flow over Niagara Falls in summer as well as in winter?
2 Have you ever read of destructive floods in any of our great river valleys? How can such dangers be lessened?
3 Are levees the best defense against floods?
4 What is meant by water storage?
5 Could you suggest good places for water storage? What good results would come from it? Do you know of storage reservoirs? For what purpose?

CHAPTER XXII

THE STORY OF BACTERIA

THERE is a class of living things too small to be seen with the naked eye whose presence in the world affects all life. Because they are so small that a powerful microscope is required to see them, they are sometimes called *microbes.* One class of them is called *bacteria,* and the science which describes them is named *bacteriology.*

The knowledge of bacteria has come in the last century, although two thousand years ago some one said, "It is to be noticed that if there be any marshy places, certain animals breed there which are invisible to the naked eye, and yet getting into the system through the mouth and nostrils cause serious disorders." But nobody then could prove this to be true, for these "animals" could not be seen, and there were no microscopes in those days.

About 1675, Leuwenhock, the son of a Dutch lens grinder, saw through one of his lenses minute, moving forms in a drop of stagnant water. Soon some of the scientists began to study these "little animals," as they were at first called. They made drawings of what they saw, and these drawings are very much like those of the bacteria drawn by scientists to-day. Many people scoffed at the reports of the early scientists, paying no more attention to them than they would to the idle tales of a crazy man. It was nearly two hundred years after this time before anything new was learned about bacteria.

Fifty years ago there could be seen at a county fair exhibitors who, for the sum of five cents, would allow a person to look through a small telescope at the spots on the sun, or, through a microscope, at the "animals" wriggling about in a drop of water. People who looked at them thought they were as much a trick as sword-swallowing.

About seventy years ago, Louis Pasteur of France began to grow and cultivate these microbes, or dust plants, as they are sometimes called, for they appear to cling to dust particles in the air. Since then knowledge of them has increased, and they have been definitely classified by botanists as plants.

About twenty years afterward, Robert Koch declared that he believed bacteria to be the cause of disease and not the effect, as many had thought them to be. This idea gave to the science of bacteriology a great impetus, and set many to thinking and experimenting, for the world to-day believes that no expense should be spared to preserve the health of mankind. No effort to save human life is thought to be too great.

One difficulty in studying bacteria has always been that upon any particle of dust there are to be found a dozen kinds of bacteria. The problem of the scientist is to separate the different kinds so as to study them one at a time. Koch used different substances on which to grow these tiny plants. Some thrive on potatoes, others grow in gelatine, and others in beef broth. In this way many kinds of bacteria have been discovered, those that produce tuberculosis, diph-

theria, pneumonia, and typhoid fever being among the number.

Thus we see that it has been within the last fifty years that knowledge of bacteria has become of value to man, or, in other words, has been reduced to a science. The science of bacteriology is of great value not only because bacteria have much to do with disease, but also because it is the foundation of our knowledge of sanitation, or the prevention of disease. This science promotes successful agriculture and the making of many products. Bacteria play their part in tanning hides, in curing tobacco, and in making butter, sauerkraut, and vinegar.

Let us consider some of the ways that bacteria assist mankind. A tree falls in the woods; an elephant or a bird dies in the jungle. Then and there millions of bacteria in the soil and air invade the dead bodies and change them into simple elements or gases which spread out in the air or go back to enrich the soil. This process is called *decay*. Thus bacteria are of great assistance to man in helping to cause decay.

The tiny bacterial plants that live in the soil help to prepare food for the plants we cultivate. Some kinds of bacteria are harmful; but these soil bacteria are very necessary and helpful, and the farmer works hard to make the soil right for them to grow in. There are millions of bacteria in a cubic inch of fertile soil. They do not need sunlight as do most plants, but they do require air, moisture, warmth, and food.

Some kinds of bacteria set up housekeeping upon the tiny rootlets of certain plants; such as clover,

alfalfa, soy beans, and cowpeas. They take a certain element that we call *nitrogen* from the air, and store it up in little bunches or swellings on the roots of these plants, where it is ready for them to feed upon. Plants must have this nitrogen as food, and soil that contains an abundance of it is rich soil. Every farmer boy knows that the fields are richer where clover, alfalfa, or cowpeas have been growing. The reason is that millions of bacteria have been at work upon the roots, storing up nitrogen from the air for them, and for other plants that follow them, to feed upon. In this way bacteria are very helpful to man in the growing of all nitrogenous plants.

Trees, grains, and grasses in order to grow must have certain simple foods, some of which are carbon, hydrogen, oxygen, and nitrogen. Plants take carbon from the air; they get hydrogen and oxygen from water. There is plenty of nitrogen in the air, too, but plants cannot take it directly from the atmosphere. Bacteria, attaching themselves to the roots of clover, have the power of separating the nitrogen from the air and passing it on to the clover. Thus the clover grows, and when it decays it leaves much nitrogen in the soil.

Thus far we have been looking at the helpful kinds of bacteria. Let us now turn to the other side of the picture where we shall find the harmful ones. A knowledge of the bacteria of disease is important, for against these we must always be on guard. We cut a finger and allow the dust of the air to get into it, and it becomes inflamed. Some pus-forming bacteria

have entered the cut and are making pus. To guard against this, we should cleanse and bind up wounds in sterile gauze to protect them from air and dust.

The bacteria of decay must be defeated before food

Testing serum to offset fatal wood ticks

can be preserved. Most foods are subject to changes that we call *spoiling*. Some become sour, some bitter, some rancid, and some putrid. Food generally spoils because mold and mildew, which are cousins of the bacteria plants carried by the dust, have entered it and have begun to grow. We see colonies of these

plants in mold which comes on the top of jelly glasses. If we buy food in cans which bulge out at the end, we may find the contents spoiled; and if we do, it is these little plants that have caused them to spoil. When clothes are covered with mildew, or when they begin to smell musty, it is these microbes of decay that have found a home in them. So it is when milk sours, when butter becomes rancid, when cider works, or when meat or eggs spoil.

The natural place for all bacteria is the soil. When soil dries, it may become dust and be carried about in the air with the bacteria. One might think because of this that the country is a most unhealthful place for one to live. But this is not true. There is in the country air always more or less moisture to which these dust particles will cling and which will be carried to the ground; while in the dwelling house in the city the air is usually dry so that the dust bodies fill the air. The old-fashioned dusting or sweeping stirs up the particles and forces them back into the air again. That is why the vacuum cleaners and absorbent mops are used to-day instead of a broom.

Let us see how bacteria behave in milk. When milk comes from the cow, it has very few bacteria. But they are in the container in which it is placed. They fly from the clothing of the milker; they fall from the hide of the cow. Unless the udder of the cow has been washed, they fall with the particles of dirt into the pail. Straining will remove the larger particles of dirt, but the bacteria remain.

Since milk is a perfect food, all sorts of bacteria

will thrive in it. They multiply rapidly until there are so many of them that the milk becomes sour. The more bacteria there are in the milk, the sooner it sours.

Bacteria multiply much more rapidly in warm food than in cold. So if we keep milk cool, we reduce the

Preparing food for bugs and bacteria

number of bacteria and thus the milk stays sweet longer.

The modern method of preserving milk is by destroying the bacteria. The milk may be heated to the boiling point; the heat kills all bacteria except the spores. Then if no others are allowed to get into the milk, it will keep for a long time. But most people

do not like the taste of boiled or scalded milk. So the more usual method is to heat the milk to a temperature of from 140 to 160 degrees, which is called *Pasteurization.* This process is named for Pasteur, who was the discoverer of modern bacteriology. The pasteurizing heat kills the principal disease bacteria, but it does not kill all of those that cause milk to sour. The milk bottle is then covered with a pasteboard cap which prevents more bacteria from entering. This process will keep milk sweet considerably longer than when it is untreated.

Questions and Problems

1 Man has only recently come to know about bacteria. Why?
2 Why has the study of bacteria been so difficult?
3 Tell how certain kinds of bacteria are enemies of man while others are friends.
4 What interesting relation is there between certain bacteria and such crops as clover and alfalfa?
5 Discuss bacteria and milk.
6 What is Pasteurization and whence came the name?

CHAPTER XXIII

JENNER, THE CONQUEROR OF SMALLPOX

EDWARD JENNER was born in England in 1749. Before he was nine years old he gathered a collection of the nests of the dormouse and was interested in all kinds of insects and animals. He studied medicine and became a surgeon in his native village. But he kept up his interest in nature and found time to gather together a museum. Everybody liked Dr. Jenner because of his kind heart and his good temper. He was a good singer, a fair violinist and flute player, and a very successful writer of verse.

In 1788 he wrote a paper on the cuckoo, but he was more interested in a disease on the hands of people who milked cows. Other doctors had noticed the disease, but had not studied it closely.

When Dr. Jenner was studying at Sudbury, a young country woman came to him for advice. While talking to her, he chanced to speak of smallpox, which was a terrible disease sweeping the land every few years. The young woman said she could not take the smallpox because she had had cowpox. This was a new idea to Dr. Jenner, but she declared it was true. She told him that everybody in her neighborhood had proved this to be true. Every milker of cows, she said, who had ever caught a certain infection from the cow's udder was after that absolutely safe from smallpox. Dr. Jenner asked other physicians about it, but they said it could not always be relied upon. Some said it was only a foolish notion of ignorant people.

Jenner, however, thought it reasonable, and he began to investigate cowpox. He found that persons who had had cowpox were so certain they were safe from smallpox that they allowed Dr. Jenner to expose them to that disease to prove it. They did not take it.

Jenner then conceived the idea of spreading cowpox, which is a harmless disease, in order to ward off the dangerous smallpox. He said, "If a man can catch the cowpox from a cow, why may not one person get it from another person?" He took the poisonous

Making vaccine for smallpox

germs from the cow and planted them under the skin of his patients and gave them cowpox, after which

The first vaccination

they were immune from the dreadful smallpox.

Next he took the germs from a person who was ill with the cowpox and gave the milder disease to others. He had solved the problem of vaccination, which is merely spreading cowpox by inoculation in order to prevent smallpox. He proved it by testing a healthy

boy aged eight. The lad was inoculated with the cowpox from the hands of a milkmaid and contracted cowpox. Jenner then inoculated the boy with smallpox, and he did not take the disease.

Jenner was now certain of his ground. He therefore published his new discovery to the world. In the following year thirty-three physicians and forty eminent surgeons signed a statement that they believed in the new discovery of Jenner. The king and royal family of England bestowed great attention upon Jenner, and the new practice of vaccination began. Parliament voted him two grants of money, which amounted to what would be one hundred thousand dollars to-day.

Vaccination gave such relief from the fear of the dreaded scourge that clergymen in Geneva and Holland praised it from their pulpits. In some places in Europe processions were formed for receiving vaccination. Jenner's birthday was celebrated as a feast day in Germany, and the first child vaccinated in Russia was named "Vaccinov," and was educated at public expense.

In six years news of the discovery had reached the most remote corners of all civilized lands, and the happy tidings were even made known among some of the savage nations.

Honors were showered upon Jenner from the Old and the New World. On one occasion Jenner requested the Emperor Napoleon, who hated the English bitterly, to release a certain Englishman held a prisoner in France. Napoleon was about to refuse

Edward Jenner

when the name of Jenner was mentioned to him. "Oh," said Napoleon, "we can refuse nothing to that man."

In a few years smallpox ceased to be the most dreaded of all diseases, because for a time it was the only disease for which a sure remedy was known.

India has always been a land where smallpox raged. During the World War when diseases threatened all nations, nine millions of people in India were vaccinated without a single death therefrom. Other millions were vaccinated in the Philippine Islands, and smallpox disappeared there also.

Jenner's plan of vaccination is now used to prevent other diseases. All soldiers entering camp in the United States in the World War were vaccinated to prevent typhoid fever.

Questions and Problems

1 Read any stories you can find about the dreadful scourges of smallpox that used to sweep over Europe.
2 How are people vaccinated to-day?
3 Do men vaccinate against other diseases than smallpox? What, if any?
4 In matters of germs and disease whose advice shall we follow?
5 How is smallpox dealt with in our cities to-day?

CHAPTER XXIV

LOUIS PASTEUR DISCOVERS GERMS

LOUIS PASTEUR'S father used to come home at night from his hard day's work in the tanyard and take his little son on his lap and say: "Oh, Louis, if you could only become a professor in the college of Arbois, how happy I should be! Here I work all day with those evil-smelling skins, tanning them for leather. Many hard years I spent in camp as a soldier. I want you to have an easier life, my son. You must have an education."

Louis was only two years old; so he played with his father's whiskers and laughed. And Louis' mother smiled and said, "Yes, our boy must have an education." But in their most beautiful dreams for the future of their son, they had no idea of the great man he was to become.

If they could have looked forward sixty years, they would have seen on the door of the very house where they were living a plate with gold letters, saying:

"Here was born Louis Pasteur
December 27, 1822."

The family soon moved to Arbois, where Louis' father had a tanyard of his own, and Louis played in the yard and thought little of the future. When he started to school, his father kept watch over his lessons, urging him to study every night. But in the day-

time Louis liked to play. He sometimes ran away from school to go fishing. He liked to draw, and instead of studying he made pictures of his teachers and his classmates. The likenesses of these were very good, so good that had Louis lived to-day and attended a modern school, his teachers would have urged him to study art. Perhaps with his talent and the hard work which he afterward showed he was willing to do, he might have been a great artist instead of a great scientist. But then he was only thirteen and did not think much of his future, nor was he very industrious.

However, a few years later he began to realize how hard his father and mother were working to educate him; so he put away his fishing rods and his drawing pencils and began to study in earnest. As he forged ahead of the other students, his teachers began to take note of him. They said: "He is a wonderful thinker. He will go far."

"You must think of the great University," said one of his teachers. "Some day you may teach there!"

Louis became greatly interested in chemistry. He asked his professor many questions that the poor man could not answer. Louis heard of an apothecary who had written noted articles on chemistry, and asked to study with him on Saturdays. The lad performed many experiments of his own. He astonished his teachers by showing them how much phosphorus he had obtained from the bones of the meat he bought for his meals.

When he was ready to enter the University, he took the examinations and stood fourteenth on the list.

This did not satisfy him. So he studied hard another year, working for his board. This time he passed fourth on the list. By this time he was so absorbed in his chemistry that he thought of little else.

In the University he had two wonderful teachers. One was quiet and exact; the other was bubbling over with enthusiasm. With these men to encourage him, Pasteur lived and breathed and dreamed chemistry. At twenty-five he had discovered some new laws and proved them to his teachers. One discovery was that two substances that chemists had always supposed to be different were one and the same. One of his professors made him come and perform the experiments in his own kitchen before he was convinced.

Louis was made an assistant professor of chemistry at Strassburg. So engrossed was he in his science, it is said that on his wedding day some one had to go to his laboratory and remind him that it was time for the ceremony.

Now he began to make some of the wonderful discoveries that have saved thousands of lives all over the world. In the southern part of France the people made their living by raising silkworms. Their homes were full of racks where they placed mulberry leaves for the worms to eat. All at once the worms began to die. The malady grew worse. The eggs would not hatch, and when they did, the young worms would not eat, and there was danger of there being no more silk cocoons. The people sent to Spain and Italy for more worms, but in time these sickened and died. Every silk producer feared he would lose his business.

Finally, in 1865, the silk raisers sent a petition to the French government to help them.

Some one said: "Louis Pasteur is the one to do it. He is not afraid to try something new."

Pasteur came to southern France. He examined the worms under his microscope and discovered small particles on their bodies. Then he took healthy worms and compared with them. He believed that these particles, or parasites, caused the disease from which the sick worms were suffering, but how did the well ones get it from those that were sick?

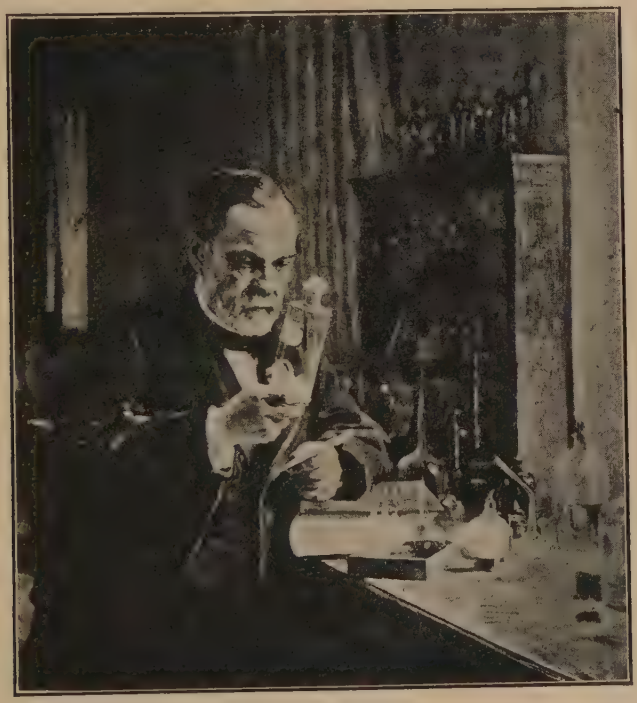
After many experiments he discovered that when a healthy worm ate a leaf over which a sick one had crawled, it, too, got the disease. The silkworms have a little hook underneath their bodies. When a sick worm crawled over a well one, he found that the little hook pricked the skin of the well one and gave it the disease. He separated the well from the sick and destroyed the sick ones and all of their eggs. In time he controlled the disease and saved the silk industry of France.

In the meantime he had learned some wonderful truths that have been a great help in checking and curing other diseases. First of all, he had discovered that there are such things as disease microbes, which carry disease from one person to another.

By many successful experiments on animals, he learned how to check disease in man. He practiced with chickens that had cholera and with sheep sick with fever, and used his results in treating mankind.

Jenner had discovered that vaccination with the

virus from cowpox would prevent smallpox, but Pasteur went much farther. He was fearless in his experimenting. He proved to his own satisfaction that if the skin was unbroken, contagious disease microbes could not enter the body, and in his laboratory he



Louis Pasteur

handled all forms of diseases. To him were sent animals and samples of blood of persons who had the most dangerous fevers. He inoculated white mice and

rabbits and dogs and even cattle, first producing disease, then searching for a remedy.

Many dogs and rabbits lost their lives in the interest of science, but Pasteur was merciful. He used to say, "I have never killed even a bird for sport; but when it is a question of saving human life, I have no scruples about sacrificing animal life." However, when there was an operation that would cause suffering, Pasteur always chloroformed the animal.

Some one tells of seeing him one day in his laboratory where a mad dog was tied to the table. The dog was foaming at the mouth, while Pasteur drew some of the poison saliva into a tube in order that he might find a cure for hydrophobia.

Some owners of cattle and sheep ridiculed Pasteur and challenged him to a trial. Pasteur accepted. Sixty sheep were put at his disposal. He vaccinated twenty-five of them against anthrax. Some days later these and twenty-five others were given the anthrax germs.

Pasteur then said that the second lot of twenty-five sheep would all die, while the first lot that had been vaccinated would live. It was arranged that believers and unbelievers should meet on June 2, 1881, at the farmyard where the sheep had been placed to celebrate a victory or to announce a failure.

When Pasteur arrived at the farmyard at two o'clock in the afternoon, he was received with much applause. There were present many distinguished men, some of whom had ridiculed his teachings. Twenty-two of the unvaccinated sheep were dead and

lying side by side. Two others were breathing their last, while the remaining one was ill of anthrax. It died that night. All the vaccinated sheep were in perfect health. It was a wonderful proof and a great victory for Pasteur.

Shortly after completing his work in southern France, his left side became paralyzed. He hastily arranged all the knowledge concerning his discoveries so that some one else might go on with them. Though he was a cripple for the rest of his life, in two years he had regained his health to such an extent that he continued his work.

Dr. von Behring of the Pasteur laboratory found the antitoxin for diphtheria; he discovered and bottled up the germs that cause the disease. In the Pasteur Institute, by many experiments on guinea pigs and birds and other animal life, scientists found that by planting a weak microbe under the skin they could make the animal immune to the strong microbe. That is, by giving him the weak microbe they so changed his system that it could fight off the disease brought by strong microbes. In other words, Pasteur said he could fight poison or toxin with the same poison or toxin. To-day every doctor uses antitoxin for diphtheria. It is made from the blood of horses which have been made immune by giving them a little of the toxin at a time until they are proof against the poison.

Every new discovery in science has to fight for its place in the world. Pasteur had many battles to prove to other chemists that he was right. Over and over he performed his experiments to prove his new laws.

The pasteurization of milk was discovered when Pasteur found that germs thrive better in some temperatures than in others. He taught the use of cold packs in reducing fever in typhoid. Around the discovery of disease microbes is built the modern treatment of most illnesses.

Questions and Problems

1 Pasteur concentrated all his time and study on one subject. Do you think that wise? Why?
2 How else did Pasteur differ from most men?
3 How did he solve the problem of the silkworm?
4 What do you understand antitoxin to mean?
5 Tell the story of the vaccinated sheep.
6 Why should mankind erect a great monument to Pasteur?
7 Should he be exalted more than a great warrior such as Napoleon?

CHAPTER XXV

ANÆSTHESIA

ANÆSTHESIA means the loss of feeling. The word is now used in connection with chloroform, ether, and nitrous oxide or laughing gas, which are used to produce loss of feeling in painful operations. A hundred years ago there was no way of preventing intense suffering in surgery. In extreme cases opium had been tried, but there was great danger in its use.

Dr. Horace Wells has the honor of being the first discoverer of a practical anæsthetic, although two other men, Dr. William Morton and Dr. James Simpson, soon added to his wonderful gift with ether and chloroform.

Horace Wells was born in Vermont in 1815. Dr. Wells was a dentist. He began his practice in the days when methods were so crude that there was great suffering attending his work. There was no college of dentistry then. Wells invented many new tools, and was soon looked upon as the most successful dentist in Boston.

For a time he was in partnership with Dr. William Morton and Dr. Charles Jackson, the latter being a great chemist. Later Wells opened an office in Hartford, Connecticut. Every day he was obliged to cause his patients so much pain that he resolved to find a way to lessen their suffering. He began to study the effects of nitrous oxide gas. He tested it on small

animals until he was sure that there were no bad effects. One day when he thought he had found the secret, he called his friend, Dr. Riggs, and asked him to test it. "I want you to put me to sleep and draw a tooth and see if I feel it," said Wells.

"But you have only sound teeth," objected Riggs.

"Well, take out a good one," said Wells. "I can't expect others to take this gas if I won't take it myself." So the story goes that Riggs extracted a sound tooth for Wells, who declared he was unconscious of pain.

But even at the price of a big white molar, Wells found the people slow to accept his great gift to the suffering world. Doctors and chemists at once sounded a note of warning against it and prevented its use for some time. However, a few dentists who saw what a help it would be in their practice made use of it.

Soon after this experiment, Wells went to Europe to recover his health. He studied in the hospitals there, and on his return he attempted to introduce the use of anæsthetics into the hospitals in New York. Chloroform had been discovered about 1831, and Sir James Simpson had brought it to the attention of the world in 1848.

Wells declared that chloroform was better than gas. He experimented with it himself, but he did not know its danger, and in time his mind became affected from the use of the drug. In an insane moment he took his own life, not three years after his discovery of gas.

In 1846 Dr. William T. G. Morton performed in a

large hospital an operation in which he used sulphuric ether. Morton had been at the Medical College in Boston, and had found that sulphuric ether could be breathed without injury and that it rendered the patient unconscious. He had it patented in the United States and called it "Etheon." Soon surgeons and dentists began using it.

Dr. Charles Jackson claimed to have discovered that ether was an anæsthetic before Morton made the discovery. This enraged Morton, and when a prize offered by the French Academy of Science was divided between the men, Morton refused to accept his half. He would not share the honor with Jackson, and did not want part of the reward.

Morton appealed to Congress to protect his rights under his patent, and our government appointed a committee of physicians to ascertain if the discovery was really Morton's. They gave the credit to Morton. He also won a lawsuit before the Supreme Court; but the time and expense of this fight ruined his business. He finally became a stock farmer and began raising fine cattle.

Dr. Charles Jackson was a noted chemist and much respected by his fellows. He studied medicine at Harvard and in Paris. On his return from France he met Morse, the inventor of the telegraph, and gave him the idea of some of the new electrical devices in Paris. This information led to Morse's invention of the telegraph.

Jackson's discoveries of anæsthetics date back to 1834, when he dissolved chloroform in alcohol and

cured an aching tooth. Once in experimenting he breathed chlorine gas into his lungs, and to relieve the pain he breathed sulphuric ether. This was about 1846, the year that Morton first reported his discovery. Jackson claimed that he told Morton about the ether, and that he, Jackson, made a mistake in not making his discovery known at once. His fight with Morton was long and bitter. He spent the last seven years of his life in an asylum for the insane.

To-day the world gives Wells the credit of introducing the use of laughing gas, and Morton the honor of first using ether, because he first demonstrated it to the world.

Questions and Problems

1 What do you know of chloroform? When is it to be used?
2 Why were dentists especially interested in it?
3 Why were people slow to believe in the Wells's discovery?
4 Which do you think is the greater gift to the world, vaccination or chloroform? Why?

CHAPTER XXVI

GORGAS CONTROLS YELLOW FEVER

ONE of the dreaded diseases that used to appear in warm lands every few years, destroying the lives of people, was yellow fever. At one time over six thousand people died in Lisbon in a few weeks from this scourge. In New Orleans in 1853 eight thousand men, women, and children died from yellow fever. Fourteen years later the disease carried off three thousand, and in 1878 four thousand people were lost in this same city. All through the tropical countries uncounted numbers of men died from yellow fever, although men of science had been working for many years to discover the cause of the illness which apparently had no cure.

William Crawford Gorgas was one of the first men to accomplish much in stamping out this disease. He was a native of Alabama, and was born in Mobile in 1854. His father was at one time President of the University of Alabama, and both his mother and his sister were librarians in that institution. General Gorgas received part of his education at Alabama University and his medical training in New York.

Gorgas first came into actual contact with yellow fever in Texas. Later, as an army surgeon, he fought it in Havana, Cuba. At that time it was thought that yellow fever was due to filth, because it so often appeared in cities where the sanitary conditions were poor. The United States decided to clean up Havana, because they believed most of the infection brought to

our country came from there. In two years they had made it about the cleanest city in the world, but there was as much yellow fever as ever. The Cubans declared that the Americans had made conditions worse. They pointed out that the cleanest parts of the city had the most fever.

President Taft appointed a Board of Investigation to discover the real cause of the fever. Some of the devoted members gave their lives to the cause. They proved beyond a doubt that the only means by which yellow fever is conveyed from one man to another is the mosquito. The female mosquito of a certain species sucks the blood of the fever patient within the first three days of the development of the disease. In from twelve to twenty days she can convey the infection by biting another person. In from three to six days the new patient may contract yellow fever.

Gorgas had tried vaccination for the disease and had failed. Then he said, "We must get rid of the mosquitoes."

"Get rid of the mosquitoes in lands that are alive with them!" said the scoffers.

It seemed impossible, but Gorgas began operations. He first screened the houses. Then he set to work to destroy the hatching places of the mosquitoes, and in one year Havana was free from yellow fever. Another kind of mosquito carried malaria. This, too, was stamped out by the campaign.

Once one of Gorgas's superiors said to him, "Is it worth all this trouble and expense to save the lives of a few 'niggers'?"

"That's not the point, General," responded this tactful Southern gentleman. "We are doing it to save your life, too, and that is worth while."

About this time the building of the Panama Canal was in progress. When the Panama railroad was built, it was said that the laying of every tie cost a human life. The United States government knew that it must improve living conditions on the isthmus if it wanted men to go there to work.

Gorgas was placed in charge of the health conditions in the Canal Zone. His great trouble was with the natives. They were immune to tropical diseases and not at all concerned about mosquitoes. It was necessary to remove every family from their home for twenty-four hours in order to fumigate the houses. It was necessary to move the fountains from the yards and to pipe water from the mountains into the cities.

Gorgas was forced to change the customs of hundreds of years. He knew just how the natives felt, but he had his work to do. He handled them so tactfully that all the houses in the city of Panama were fumigated in two weeks. Colon was also cleaned up. He built sewers and waterworks, and insisted that the citizens dispose of waste and garbage in a sanitary manner instead of dumping it in the streets as they had always done.

The streets were paved, and the cities were cleaned and the people satisfied. Some one said of Gorgas, "That man can feed you liquid quinine and make you think you like it."

It was a great task to fight mosquitoes in this new

tropical land. The mosquito lays her eggs in standing water. Kerosene placed on top of the water killed the young wrigglers by choking them when they came up to breathe. But it rained in torrents every day, so the negroes had to keep constantly busy with their kerosene cans. Hundreds of men were put to work

Colon at the entrance to the Panama Canal

with axes to cut away the tropical growth so that the sun would dry up the small pools. Swampy ground near places where people lived was drained. A million dollars was spent for copper wire to screen the houses of the workmen.

Since the yellow-fever mosquito breeds near houses, it was easier to control than the malaria mosquito. Gorgas saw to it that not even an empty tomato can

was left to collect water in which mosquitoes could hatch.

Hospitals were built, and no sick person was allowed to remain at home except by special permission. By 1908 Gorgas wrote, "It is now three years since yellow

Corozal, Panama Canal

fever has appeared in the Canal Zone." Thus he encouraged us to believe the wonderful fact that all tropical countries could be made safe.

In 1913 Gorgas went to South Africa to investigate the pneumonia deaths in the mines there. He was also called to Ecuador to conduct a campaign against yellow fever.

When the World War began, Gorgas was made Surgeon-General, and had in charge the health of four

million men at home and in France. He called together the best medical aid in the United States and completed a splendid organization.

When he retired from the army in 1918, he became associated with the Rockefeller Foundation Health Board. He died in London on his way to the West Coast of Africa. While he was ill, King George bestowed upon him a cross and star in honor of the great work he had done.

France and Italy also honored him, and he was given degrees of honor from many colleges in the United States because of his great service to the health of mankind.

Aside from his scientific success, Gorgas had many friends because of his delightful personality. He was quiet and modest, kind and sympathetic. His success in working in strange lands lay in his ability to gain the confidence of the people.

In his honor a memorial institute for the study of tropical and preventive medicine is to be built in Panama. The memorial organization has taken as its slogan, "Health to all people in all lands."

The driving out of the mosquito has roused us to battle against the typhoid-carrying fly, and we are improving sanitary conditions daily in our own land. Gorgas proved that by constant care the warm lands of the earth can be made safe for white people.

Questions and Problems

1 Give some stories of the yellow-fever scourge.
2 How came the United States to become particularly interested in stamping out yellow fever?

3 Describe the fever campaign in Panama.

4 Tell the life history of our common mosquito. What, if anything, does your Health Department do to defeat the mosquito pest?

Experiment: Take some stagnant water containing wrigglers. Put kerosene on the water and note the result.

CHAPTER XXVII

THE CONQUEST OF YELLOW FEVER

GORGAS and others gained control of the mosquito that carries the yellow-fever germs (stegomyia) by destroying the mosquito and preventing its breeding. No other such disease has been so thoroughly conquered.

But nobody had discovered the microbe itself. All that was known was that the stegomyia carried this microbe, but try as they might, the experts could not find the thing. They had trailed it, using the same methods that had been successful in detecting other disease germs, but in vain. These yellow-fever germs were known to be very small because they passed easily through porcelain filters, the pores of which were so small that most microbes were held back. It seemed possible that they might be so minute as to be entirely beyond the power of a microscope. The disease had been controlled by constant watching, but the last step to complete success was to find the germ. It was tantalizing, indeed, and the scientists would not give up the challenge.

In the summer of 1918 the city of Guayaquil, Ecuador, was suffering from a severe epidemic of yellow fever. James Bryce had said that this city was the pesthouse of South America and the last stronghold of this deadly peril, except the banks of the Amazon. When the people of Guayaquil asked the Rockefeller Institute for Medical Research of New York City to

send them some experts, the best were chosen to aid in the fight.

On the staff of the Rockefeller Institute was the eminent Japanese student of bacteria, Dr. Hideyo Noguchi. Dr. Noguchi was educated in the schools of Japan and in the Tokio Medical College. He came to the United States about twenty years ago, and almost at once joined the staff of the Rockefeller Institute.

Dr. Noguchi was selected as one of the commission to be sent, because he had long been a successful hunter of small disease germs. He knew well how to grow them in a kind of food jelly, and how to experiment with them. Thus he had discovered many germ secrets. Moreover, Dr. Noguchi was well acquainted with a disease called infectious jaundice, which is much like yellow fever. He had discovered the germ of jaundice in Japan by careful plans and hard work.

The yellow fever mosquito breeds in fresh-water containers about and in the homes of men. It is rarely found in pools of water on the surface of the ground and never in the fields and swamps. It is a domestic mosquito, clinging to buildings that are inhabited and avoiding direct sunlight.

The female lays between one hundred and one hundred fifty eggs at a time. These eggs are deposited on the surface of the water—always in a barrel, tank, tin can, flower vase, broken bottle, or the like. From each egg there comes a wriggler, or larva, which after several changes, or molts, becomes a mosquito. If it be a female, it starts at once to find a

victim from whom to suck blood. Should this victim be ill with yellow fever in the early stages, the mosquito will take up the germs in the blood. After about twelve days, the mosquito has fed the germs till they are able to give yellow fever to the victim she bites.

In Guayaquil there was no modern water system piped through the city. The water was delivered to the homes during a certain two hours each day. Thus the water had to be stored so as to last till the next day.

In the better homes it was stored high up on the walls in tanks provided with valves for letting the water out. There were about seven thousand tanks in use in the city. In the plainer homes the people used barrels, oil tins, large bowls, and all sorts of containers. Of these there were thirty thousand or more.

The American expert at first thought that the best way to check the disease would be to do away with these water containers. Before this could be done, however, a modern water system would have to be installed in the city, so that an abundance of water could be carried to the people every hour of the day. But this would require two years, and meantime yellow fever would be killing hundreds. A modern water system has since been built, but the scientists could not wait.

They next thought of screening the water vessels, but there were too many of them. Besides, the necessary wire screening was scarce, and it would require months to have a supply shipped in.

Then they thought they could strain the water through muslin and thus separate the mosquito eggs

Dr. Noguchi

and larvæ. This was discouraging, because it would require a great amount of time and care. They at last set out to find a fish that could be put into all these thousands of receptacles to devour the eggs and larvæ.

Fish had been used for this purpose before in places infested by yellow fever.

The first fish tried was a small one called a *top minnow*. It would eat mosquito eggs in streams, but in barrels and other containers it found so much other food in the water that it could not be relied upon to devour all the eggs and larvæ. Besides, it is not a hardy fish, and a slight shock produced by dipping a pail into the water will kill it. For these reasons, the experts concluded to search for another fish better suited to this need.

The next fish to be experimented with was a kind of perch called *huijas*. This fish is a voracious eater of mosquito eggs. It can be roughly handled in long trips in pails and cans without injury to it. The scientists were now sure their problem was solved. But it was soon discovered that this little perch was so unhappy in the small tanks and barrels that it would jump three or four feet out of the water to free itself from the container.

The experts then tried a little sardine which seemed just the fish to do the work. It spends most of its time on the surface just where the mosquito eggs are floating, but when any noise is heard, it quickly swims to the bottom and remains there until all is quiet again. However, this fish was not plentiful, and it would cost too much to furnish it for all the water tanks in the thousands of homes.

Finally, a little fish called the *chalaco* was tried and adopted as the most satisfactory for consuming mosquito larvæ and eggs in small dark tanks.

Chalaco are so plentiful in Ecuador that the cost was only a half cent apiece. Fishermen caught them by the hundreds from the streams, and put them in wells containing the same water in which they had been living. After a few days the fish were removed to another well containing city water, with no food except what they could get in the water. Soon they were carried in pails to the homes and put in the thirty thousand water vessels where they were happy and busy. Some of the very same fish were living two years later. So active and hungry were these little fishes that they devoured nearly all the mosquito eggs and larvæ in the water cans of Guayaquil, and that city has since been almost entirely free from yellow fever.

However, Dr. Noguchi was not satisfied until he found the germ itself. He experimented on guinea pigs, dogs, and monkeys with the deadly mosquito, and after long and careful work he found the germ in the blood of these animals. With the blood he transmitted yellow-fever germs to guinea pigs, and made a thorough study of the development of the disease and the time it takes to infect animals. He took the germs from one animal and through them gave the disease to other animals.

The germ of yellow fever is a very tiny slim spiral. It went wriggling and twisting about in the blood or in the culture food in which Dr. Noguchi raised it. The germs are so small that even the best microscope will not always show them. The yellow-fever germ proved to be not a bacterium, which is a lowly plant, but a

protozoan, or a lowly parasite that belongs somewhere between animals and plants.

No sooner had Dr. Noguchi discovered the germ than he set out to make a vaccine that would prevent the disease in men even though they should be bitten by an infected mosquito. He first killed some of the germs and inserted them under the skin of a guinea pig to see if he could make it immune. Then he tried to give it the disease by inserting live germs in its blood, and to his great joy the animal had become immune and remained so for six months. Larger doses prolonged this time. Thus had Dr. Noguchi learned how to vaccinate against yellow fever. He vaccinated some soldiers who were to be sent into an infected region, and though several of them had the fever, he found he was on the right track.

Ten thousand people in a yellow-fever district were vaccinated in 1921, and not one who received two injections took the disease. It requires fifteen days for the vaccine to become effective.

In 1921 a very severe epidemic swept into Peru where fifteen thousand cases were reported. This plague could not be stopped by vaccination, for the native population were prejudiced and would not permit it. However, by a campaign against the mosquitoes the disease was conquered.

In another case six hundred soldiers who were to be sent into a district where there was a severe yellow-fever epidemic were vaccinated beforehand, and not one took the disease. The great scientist had won a wonderful victory over another enemy of man.

Dr. Noguchi also made a serum to be used on persons already ill with yellow fever. Of one hundred and seven cases treated with the serum before the third day, only fourteen died.

Thus the scientists have conquered one more scourge of mankind. In doing so they have taken another step toward opening up the hot belt of the world as an abode for white men. With the aid of men of science we are moving more and more toward the tropics, where the abundant rainfall and warm sunshine grow food crops easily and where life is less strenuous.

Questions and Problems

1 Why was it so hard to find the yellow-fever germ?
2 Why was Dr. Noguchi just the man to put on the trail of this germ?
3 Why was Guayaquil so hard to rid of yellow fever?
4 Tell of the experiments with fish that eat mosquito eggs.
5 Describe Dr. Noguchi's victory.
6 What is a vaccine? A serum?

CHAPTER XXVIII

RADIUM, THE MAGIC METAL

RADIUM is a white powder that looks like table salt. A pound of it would be worth a thousand pounds of gold or nearly a million dollars. Radium is very costly because it is so scarce. A mere pinch of it is worth a small fortune. There are only a few spoonfuls in all the world.

But radium is so powerful that too much of it would be dangerous. If a pound or two could be gathered at one spot, it would kill people who came near. You might approach and even handle the powder without feeling any pain, but in a week or two your skin would peel off, your eyes would become blind, and death would soon follow.

Even the tiny amounts that we possess have caused harm to those who have experimented with them. One man carried in his vest pocket a small tube of it to use in a lecture, and about three weeks afterward the skin under the pocket turned red and began to fall away. A deep and painful sore formed that took weeks to heal. Radium is so scarce, so costly, and so powerful that only men of science dare to experiment with it.

When seen in the dark, radium glows like live fire. The marvel of it is that while it gives off light and heat all the time, it does not seem to lose any weight. Think of a piece of coal burning day and night for many years, always giving off light and heat but losing no weight that you could measure, and not turning to

ashes. A pound of radium will melt a pound of ice every hour and continue to do so almost forever. That is so much like "perpetual motion" that men have longed to discover for centuries. If you could put enough radium in your furnace, you would never again have to feed or clean it.

A certain scientist kept his radium tubes in a pasteboard box for a time. When the box was broken, he removed the tubes and threw the box aside. Several days later, having occasion one night to turn off the lights in his laboratory, he found the discarded box glowing in the dark. It had absorbed some of the rays of the radium. Nearly every object that comes in contact with radium becomes "radio-active."

This means that other substances get some new power from the radium, especially the power to shine or glow in the dark. Wherever darkness is a cause of danger, radium may be used to point the way to safety. A kind of radium paint is used on power-line switches where a fumble might cause electrocution. It is also used on watch and clock dials, on labels for poison bottles, on keyholes, and on the eyes of children's dolls.

You may wonder how radium, which is so costly, can be used on a two-dollar watch dial. The secret is that it is not the radium that is glowing, but the zinc sulphate that has only a tiny trace of radium. A mere pinch as big as a pin head will make the zinc shine on hundreds of thousands of watches.

If you should examine such a dial through a powerful magnifying glass, you would see the tiny explosions

of the atoms of radium. These atoms explode at the rate of two hundred thousand a second. Thus the radium bombards the zinc till it glows. While the radium will last almost forever, the zinc wears out after being bombarded for a few years. The better the zinc the longer it will glow.

It is as a cure for disease that radium is most helpful to man. It is used to treat thousands of cases of cancer each year. Many cases are cured, and in others the suffering is relieved. It is also used as a cure for tumors. Nearly every large city has a hospital that is supplied with a small amount of radium. The surgeon uses only a tiny bit, perhaps the size of a pinhead, but even that may cost many thousand dollars.

How radium was discovered is a fascinating story. In 1896, M. Becquerel, a Frenchman, was making some experiments with certain things that shine or glow without seeming to be hot. They are said to be phosphorescent. Perhaps you may have seen in damp woods what is called "fox fire." Becquerel exposed a metal called *uranium* to the sunlight until it became phosphorescent, and he then tried its effect on a photographic plate. It rained, and he put the plate away for several days in a drawer. When he developed the plate, he was surprised to find on it a better image than sunlight would have made. Thus, by a sort of accident, he discovered that Becquerel rays, or pitchblende, will yield a substance, *uranium,* that is radioactive.

Two years later Professor Curie and Madam Curie, of Paris, found that some of the pitchblende with

which they were experimenting was much more powerful than any uranium that they had used. They began to wonder if there was something in pitchblende more powerful than uranium.

Mme. Curie in her laboratory

Madame Curie was born in Poland and educated in Warsaw. She chose science as her field of study and went to Paris to pursue higher training. There she began the study of objects that glow in the dark. Finding that some of the pitchblendes were much more radio-active than uranium, she wisely concluded that

there must be some other substance in the pitchblende besides uranium, and she set to work to find it and separate it from the other elements. The Curies kept "boiling down" the waste rock left at the uranium mines until they found a strange, new element something like uranium, but different, which Madam Curie called *polonium,* after her native land, Poland.

The Curies did some more "boiling down," and finally obtained another entirely new substance, *radium,* which is the most radio-active of anything we know about. So wonderful was their discovery that the Curies beame famous almost immediately. The world's greatest scientists at once took up the study of radium.

The discovery of radium was due to the great scientific knowledge and imagination of Professor Curie, together with the patient and careful work of his gifted wife.

To obtain radium is a very difficult and expensive process. In the first place pitchblende, from which we first got radium, is not plentiful. It is found in Norway, Egypt, North Carolina, Colorado, and Utah. Pitchblende is obtained in small lumps in veins of gold, silver, and mica. From pitchblende it is easy to get uranium. But to get radium from the refuse left over is a difficult task. Professor Curie says you would have to refine about five thousand tons in order to get about two pounds of radium. Some one has said there is more gold in sea water than radium in the earth. Much of the radium in the world is now found in America. A great portion of it comes from car-

notite found in the Paradox Valley in Colorado.

In 1909 Joseph Flannery of Pittsburgh went to Europe to find a cure for his sister who was afflicted with cancer. He learned that radium alone would help her, but that there was not enough radium in Europe to serve his purpose. So he returned to America, determined to make his own radium in this country.

The field was absolutely new, but he went to the task bravely. He finally found and got control of a low-grade ore in Colorado. Every one discouraged him, but in 1913 he produced the first radium made in this country. The ore was obtained from narrow seams in the ground. It was packed in sacks and drawn by mule team to the railroad sixty miles away. Thence it is shipped in carload lots to an extraction plant, in Pittsburgh or Orange, New Jersey, nearly three thousand miles away.

In order to obtain one thimbleful of radium the plant must handle and reduce a trainload of ore. It must go through five thousand different stages which require six months' time.

Experiments have been made to find out the effect of radium on mice, guinea pigs, and other animals. If they are exposed to the light of radium long enough, they all lose their fur, then become blind, and finally die.

The great thing about radium besides its tremendous power is that every ounce that is added to what we already have is pure gain, for the metal will last almost forever. It will continue to give off light and

heat for sixteen hundred years, and even then it is one half as powerful as at the start. After a second period of sixteen hundred years, we would still have a quarter of the amount we started with. It will go on like this for twenty thousand years, when it will at last change into common lead.

Scientists believe that this mysterious metal will be a key to the unknown in science. Through radium they hope to learn how to change one element into another. It would be interesting and profitable to change metals into gold. But it would be worth more to man to learn how to get all the power from the atoms to do man's work. If we can only unlock this secret of nature, we shall have a new world. For with all this tremendous power man could work wonders.

Questions and Problems

1 Name the substances mentioned in this chapter and see what you can learn of them from the encyclopedia.
2 Explain radium paint.
3 Why is radium so costly?
4 Tell about its discovery.
5 Why is it thought to be a key to the unknown in science?
6 Give two reasons why you should not experiment with radium.

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